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ABSTRACT

This study, the first of two parts, had two main purposes. The first was to obtain desirable subject matter for an instructional program in nondestructive testing through a survey of selected manufacturing and service companies in Texas, and the second was to determine the degree of emphasis that should be placed on each subject. Fifty-nine categories of business were represented in the sample population of 276. A questionnaire, which utilized a rating scale, was used for collecting the data which was analyzed by chi-square procedures at the .05 level. It was concluded that subject matter shown in the questionnaire should be retained and formulated into an instructional program in nondestructive testing and inspection. Because there is a shortage in this field, graduates of the proposed program will find positions, and their training will be reduced due to their knowledge and skills. It was recommended that program planners should incorporate the subject matter contained in the main areas of: penetrant, magnetic particle, eddy current, ultrasonics, and radiographic nondestructive listing and inspection. A related document, the instructional program, is available as VT 014 417. (Author/GEB)

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A STUDY OF NONDESTRUCTIVE TESTING AND INSPECTION PROCESSES USED IN INDUSTRY WITH IMPLICATIONS FOR PROGRAM PLANNING IN THE JUNIOR COLLEGES OF TEXAS

By

Vernon L. Stokes
Principal Investigator

Dr. William A. Miller
Project Director

Denton, Texas

August, 1971

FOREWORD

This research project was conducted under the direction of North Texas State University in cooperation with the Division of Occupational Research and Development, Texas Education Agency.

The study is composed of two parts:

A Study of Nondestructive Testing and Inspection Processes Used in Industry with Implications for Program Planning in the Junior Colleges of Texas

An Instructional Program for Training Nondestructive Testing and Inspection Technicians

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The hundreds of persons in industry and in educational institutions who worked with me in carrying out the objectives of this study are also due special thanks.

A special recognition is due to my wife Dorothy, who typed the contents of this study. Her secretarial support and encouragement are greatly responsible for the accomplishment of this study.

ABSTRACT

Stokes, Vernon L., A Study of Nondestructive Testing and Inspection Processes Used in Industry with Implications for Program Planning in the Junior Colleges of Texas. Doctor of Education (College Teaching), August, 1971, 211 pp., 11 tables, bibliography, 42 titles.

Nondestructive testing is the science that includes the measurements of a material's properties without changing the characteristics of those properties. The testing and inspection processes are particularly applicable to engineering designs of stressed materials. The problem associated with this study was obtaining relevant subject matter pertaining to nondestructive testing and inspection processes for program planning purposes in the junior colleges of Texas.

The study had three main purposes: to survey selected manufacturing and service companies in Texas in order to obtain desirable subject matter for an instructional program in nondestructive testing, to determine the degree of emphasis that was to be placed on each subject so that a meaningful program would be planned, and to determine if there was a significant difference in emphasis placed on each selected subject by technical personnel from industry.

The three hypotheses tested during the study are as follows: There will be no significant difference in emphasis

placed on each selected subject by personnel from manufacturing and service companies who are engaged in nondestructive testing and inspection processes. There will be no significant difference in emphasis placed in major areas of subject matter by personnel from manufacturing and service companies who are engaged in nondestructive testing and inspection processes. There will be no significant difference in emphasis placed on each selected subject by nondestructive testing and inspection supervisors and operators.

An initial population of 547 manufacturing and service companies in Texas was formulated from which the sampling population of 276 respondents was identified. Fifty-nine categories of business were represented in this cross section of Texas industry. A comprehensive questionnaire, which used a rating scale for rating the relative importance of subject matter to be included in the proposed program, was sent to each of the respondents. During a three weeks period of time, the survey produced a 71.7 per cent return.

Data were organized and evaluated in order to determine the following findings: Hypotheses were tested at the .05 level by use of the chi-square procedures for testing independence of variables. Hypothesis I rejected twenty-four items of subject matter while Hypothsis II rejected all main areas of subject matter. Hypothesis III rejected nineteen items of subject matter. Forty-one per cent of the population indicated that the technical subjects should be taught

in general, whereas 32.1 per cent indicated that a detailed discussion was essential, and 26.5 per cent pointed out that a brief discussion was sufficient.

The following conclusions were drawn: Subject matter shown in the questionnaire should be retained and formulated into an instructional program in nondestructive testing and inspection. Related manufacturing fields should use more of the nondestructive testing and inspection processes. Because there is a shortage in this field, graduates of the proposed program will find positions and their training will be reduced due to their knowledge and skills.

From the conclusions, the following recommendations were made: Educational institutions, especially the junior colleges, should implement programs of instruction in nondestructive testing and inspection if the need exists in their geographical areas. Program planners should incorporate the subject matter contained in the five main areas of nondestructive testing and inspection within their programs. Further studies should be made to ascertain specific courses of instruction needed in the overall program. Funds for implementing these programs should be provided by the Texas Education Agency and the federal government.

TABLE OF CONTENTS

Page

LIST OF TABLES v

Chapter

I. INTRODUCTION 1

  Statement of the Problem
  Purpose of the Study
  Hypotheses
  Limitations of the Study
  Basic Assumptions
  Definition of Terms
  Background and Significance of the Study
  Organization of the Study

II. RELATED LITERATURE 17

  Introduction
  Nondestructive Evaluation
  A Related Industrial Study
  The Fourth International Conference of Nondestructive Testing
  Recent Development of Formal Training Programs
  Related Technological Studies
  Summary of the Literature

III. PROCEDURES 44

  Gathering Data for the Study
  Interviewing Personnel
  Constructing the Survey Instrument
  Instrument Validation
  Identifying the Population
  Sample Size and Population Representation
  Accomplishing the Survey

IV. ANALYSIS OF DATA 62

  Introduction
  Hypotheses Testing
  Recommended Time to Be Spent in Teaching Subject Matter

Page

General Education
Additional Subject Matter
Importance of Phases of Nondestructive Testing
Recommended Research in Nondestructive Testing
Other Forms of Energy Needed in Support of Nondestructive Testing
Branches of Industry Needing Support of Nondestructive Testing
Technologies Recommended for Instruction in Nondestructive Testing
Nondestructive Testing Employment and Training Data
Additional Program Development Recommendations

V. SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS 83

Summary
Findings
Conclusions
Recommendations

APPENDIX 90

BIBLIOGRAPHY 208

LIST OF TABLES

Table Page

I. Nondestructive Testing Methods for Materials Evaluation 18

II. Summary of 4 Year Colleges and Universities . . 26

III. Significance of Major Areas of Subject Matter According to Response Data 67

IV. Population's Response Showing Degree of Emphasis 68

V. Response to Degree of Emphasis in General Education 70

VI. Response Data Pertaining to Importance of Phases of Nondestructive Testing 73

VII. Technologies Recommended for Instruction in Nondestructive Testing 76

VIII. Nondestructive Testing Employment Data 77

IX. Response to Question: "Would You Hire a Technician Who Has Completed the Above Training if Space Were Available?" 78

X. Response to Question: "Would a Graduate of This Proposed NDT Program Reduce Your OJT Time?" 79

XI. On-The-Job Training Hours Assigned to New Personnel 80

CHAPTER I

INTRODUCTION

Today, the process of metal inspection provides a high degree of assurance to the designer that metals can be relied upon to hold their assigned loads safely. This assurance is based on man's ability to detect faulty metal and withdraw it from service. The detection process is known as nondestructive testing and inspection. It is this process that assures a high degree of safety for our nation's aircraft and other highly stressed structures. However, skilled personnel are not available in sufficient numbers to operate the testing and inspection equipment.

During the years following World War II, man accumulated technical knowledge much faster than he could use it. Part of this knowledge explosion resulted from increased demands in load-carrying structures such as in supersonic aircraft and space vehicles. Greater load requirements brought in the new materials, especially metals, and these were called upon to hold even greater loads and to withstand increased pressures and temperature differentials. In effect, these new demands caused manufacturing problems in producing sound metal. Further, the demands pressed manufacturers to provide testing and inspection equipment which was capable of controlling the high quality of the new metals by detecting faulty conditions. Along with the need for testing and inspection equipment was the requirement for qualified personnel to operate the equipment.

The requirements for sound metal brought forth a sophisticated array of equipment capable of detecting unsound metal and assuring a high degree of quality control. However, enough qualified technicians have not been provided to operate the equipment. Therefore, a severe technician shortage has developed. The yearly requirement is exceeding the supply. Bowen (1), in his analysis of the critical need for technicians, predicts a shortage of 350,000 technicians of all types in 1975. Much of this shortage is earmarked for nondestructive testing and inspection methods. Bowen further stated that,

> Unless the U. S. remedies this shortage of technicians our economic expansion may be seriously retarded. The shortage of such a critical manpower resource limits the capability of corporations to create new jobs, expand facilities and productivity, and apply advanced technological practices (1, p. 6).

Bowen also predicted that our educational institutions will provide only one half the total number of needed technicians. Consequently, industry has challenged the schools to provide an adequate number of qualified technicians to man the awaiting equipment.

Technicians represent a large group of skilled personnel in industry who function at the sub-engineer level of capability. Their responsibility includes work delegated from the engineer, scientist, or other professional person. A major cause of this delegation of responsibility has been a great increase in knowledge.

> The explosion of new scientific knowledge has caused changes in education so that the recently graduated scientist or engineer often has had limited laboratory experience and functions more as a theoretical, diagnostic, interpretive, creative, or administrative professional than in the past. He now must delegate much of his scientific work to other skilled members of the scientific team (12, p. 2).

The delegation of such an important responsibility requires assurance of the availability of competent personnel in order that production functions continue. One of the responsibilities of the technician is to ". . . supervise, or assist in installation, and inspect complex scientific apparatus, equipment, and control systems" (12, p. 4). The following technician capability is pointed out in _Criteria for Technician Education_:

> A requirement of usually 2 years and less than 4 years of rigorous, college-level study . . . the supporting mathematics; and the special techniques, processes, apparatus, related technical and interpersonal skills, services, and competencies in order to be employed as a beginning technician (12, p. 7).

Experience has shown that coordination between industry and educational institutions has provided compatibility in many plans and educational programs. However, the types of manufacturing and inspection processes vary to a great degree with respect to nondestructive testing and this variance increases the complexity of coordination. Therefore, complexity in manufacturing along with the needed levels of skill have left uncertainty with respect to the desired subject matter for a program. Uncertainty exists not only in the processes of manufacture but also in the specific types of products produced. Consequently, this study was accomplished in order to provide data for nondestructive testing, inspection, and evaluation program formulation in the junior colleges.

Statement of the Problem

The problem was obtaining relevant subject matter pertaining to nondestructive testing and inspection processes used in industry for program planning purposes in the junior colleges of Texas.

Purpose of the Study

This study was conducted for the following purposes:

1. To survey selected Texas manufacturing and service companies in order to obtain information and desirable subject matter for an educational program pertaining to nondestructive testing and inspection processes.

2. To determine the degree of emphasis which was to be placed on each selected subject so that a meaningful program could be planned.

3. To determine if there was a significant difference in emphasis placed on each selected subject by technical personnel from manufacturing and service companies.

Hypotheses

The following hypotheses were tested during the study:

1. There will be no significant difference in emphasis placed on each selected subject by personnel from manufacturing and service companies who are engaged in nondestructive testing and inspection processes.

2. There will be no significant difference in emphasis placed in major areas of subject matter by personnel from manufacturing and service companies who are engaged in nondestructive testing and inspection processes.

3. There will be no significant difference in emphasis placed on each selected subject by nondestructive testing and inspection supervisors and operators.

Limitations of the Study

This study was limited to 547 manufacturing industries and service companies within the state of Texas.

Basic Assumptions

It was assumed that nondestructive testing, inspection, and evaluation data needed for program planning purposes could be obtained from selected Texas manufacturing and service companies through the medium of a questionnaire and by means of personal interviews.

Definition of Terms

For the purpose of this study the following definitions have been formulated:

Nondestructive testing and inspection is the science that includes the measurements of a material's properties without changing the characteristics of those properties. The process detects surface and sub-surface flaws and irregularities of solid materials for evaluation purposes. Because evaluation invariably follows inspection as a result of testing, the abbreviation NDE (nondestructive evaluation) is used and is often used interchangeably in industry with NDT (nondestructive testing) or NDI (nondestructive inspection). In all instances, however, nondestructive evaluation of the material is the primary objective. Included in the processes discussed in this study are specific tests known as magnetic particle, liquid penetrant, eddy current, ultrasonic, and radiographic.

Liquid penetrant testing includes the use of liquid, often an oil, in which is suspended a solid particle such as a coloring or fluorescent agent. Surface flaws are exposed when the liquid penetrates the flaw.

Magnetic particle testing involves the use of electricity to cause the ferrous part which is to be inspected to become temporarily magnetized. When iron powder contacts or is attracted by surface cracks and other surface or near surface irregularities, magnetic fields are formed at the cracks or irregularities. The flaw's outline is observable.

Eddy current testing involves electromagnetic induction principles whereby the metal to be tested is placed in a varying magnetic field. The test object receives currents which introduce additional magnetic fields. Variance in the material (flaws and irregularities) causes variance in the magnetic field and flaw detection.

Ultrasonic testing is based on the principle of energy beamed into a material and then recorded. Deviation in the material (flaws and irregularities) causes deviation in indicated energy and flaw detection.

Radiographic testing utilizes radiation as the means of penetrating solid materials. Deviation in the material (flaws and irregularities) is recorded on film. X-ray and gamma ray testing are common tests performed.

Technician is the title given to the skilled person who supports activities in the engineering sciences and is capable of functioning at the sub-engineer level of capability. He has at least two years of formal college training and education or equivalent.

Manufacturing industry is the industry primarily engaged in the manufacture, production, and control of a part or commodity requiring nondestructive tests and inspection during manufacture.

Service company is the company primarily engaged in a service that requires its vehicles, structures, or apparatus to be subjected to periodic nondestructive tests and inspections after the part or commodity has been produced.

Supervisor is a person responsible for supervision of inspection activities; management, service, and distribution of inspection equipment; planning and set-ups for inspections; and engineering control of evaluation functions.

Operator is a person who performs testing and inspection processes with the use of nondestructive testing apparatus. He may also evaluate results of inspection.

Background and Significance of the Study

Present day nondestructive testing and inspection techniques are mostly creations from the twentieth century, but man's persistence for excellence and his inherent curiosity date back to ancient times. Long ago, man discovered that he could detect flaws in a solid material by tapping it and listening for changes in sound patterns. Through the centuries this elementary inspection process continued. Then, in recent times, discoveries were made in penetrating rays of energy, called X-rays by Roentgen. Late in the nineteenth century, Roentgen stated ". . . I have for example photographs . . . of a metal piece, the inhomogeneity of which becomes recognizable by the X-rays . . ." (8, p. 11).

Prior to Roentgen's discovery, the compass had been used to detect cracks in metal through magnetic observations. Then, early in the twentieth century, other forms of energy, particularly electricity and high frequency sound waves, were used in the process of finding flaws in solid materials.

It was not until the 1930's, however, that increased discoveries in inspection techniques provided a background for an organized approach to nondestructive testing procedures. Organized approaches were first visualized by the professional societies.

> In 1935 the American Society for Testing Materials organized their first symposium about radiography and X-ray diffraction methods . . . 1941 followed the foundation of the 'Society for Nondestructive Testing', which produced already one year later its own magazine 'Industrial Radiography', since 1964 called 'Materials Evaluation' which now covers the whole range of nondestructive testing (8, p. 13).

Today, the national organization concerned with nondestructive testing, inspection, and evaluation is the American Society for Nondestructive Testing. During the last three decades great accomplishments have been made through the efforts of this society in the many processes concerned with nondestructive testing. These processes are now woven into much of American industry so that evaluation of a material's capabilities can be accomplished. In evaluating a material's or a product's capabilities, according to Davis, Troxell, and Wiskocil, it is often ". . . desirable to know the characteristic properties of a product without subjecting it to destructive tests" (3, p. 266). Efficiency in inspection processes has increased to such a high degree that many properties of a material can now be verified by nondestructive tests when qualified personnel and equipment are available.

Today, the problem is not the absence of needed equipment for certifying materials, but the absence of sufficient numbers of qualified technicians needed to operate the equipment. The complexity of testing and inspection equipment is accelerating rapidly. As an example, X-ray is used to find holes deep within metals. In order to conduct this test and to find the holes, special training in radiography is needed. According to Halmshaw, "Radiography is a flaw detection method and any flaws revealed must be assessed for their significance and influence on the serviceability of the structure" (5, p. 359). Assessment requires thought and comprehension; therefore, education and training have become necessary in order to provide sophisticated inspection systems which are followed by effective evaluations. The field of radiography, according to Turner,

> . . . has increased at the rate of some 6 per cent per year for the last 15 years . . . we are faced with factors which could shorten this period of growth . . . The Vietnam war is a large factor . . . Another factor exerting, we hope, an even greater effect is education . . . We are sensing a greater emphasis in the education of metallurgists and engineers on nondestructive testing in universities and colleges across the country (10, p. 16A).

Determination of serviceability of an engineering material often uses several of the nondestructive procedures. In this respect, radiography is only one of several tests and energy systems used in determining the characteristics and serviceability factors of a material. For example, the General Dynamics plant in Fort Worth is employing an Acoustic Emission Monitoring System for finding cracks in complex structures. According to Nakamura, "The acoustic emission technique has been a successful new tool for the past several years for nondestructive testing and materials evaluation" (9, p. 8). A summary of this process follows:

> An acoustic emission monitoring system designed to detect, in real time, initiation and growth of cracks in a complex structure during static as well as fatigue testing has been developed. The system consists of arrays of acoustic sensors, logic circuits and output devices. An effective spatial and frequency-filter combination permits the use of the system in the presence of the heavy background noise ordinarily encountered in the testing of a large, complex structure. The system is being used successfully in static and fatigue testing of full-scale, as well as small-scale specimens of aircraft components and structures (9, p. 8).

Basically, "Nearly every known form of energy has been used to establish workable systems" (11, p. 3), according to the United States Department of Commerce. Some of these other workable systems in the area of nondestructive testing include magnetic particle, liquid penetrant, eddy current, and ultrasonic. "The most efficient testing system may include all known nondestructive techniques; however, until appropriate techniques for all applications have been developed, no system of evaluation can be completely efficient" (13, p. 1).

If, on the other hand, the characteristics of the material require strength verification, then a destructive test is often necessary. This test destroys the sample of the usable material as its strength is calculated. According to Breneman, "Strength of Materials is that branch of the science of engineering which studies the effects of forces acting on pieces of deformable materials and the resulting deformations" (2, p. 1). Nondestructive testing does not normally seek the strength of a material; it provides, however, many of the needed engineering properties (mechanical and physical) such as the detection of microcracks which precede failure in hardened steel. "The ability of a crack to propagate in these hardened materials appears to be related to the lack of sufficient plastic flow to blunt the crack" (6, p. 116).

The nondestructive testing process is suffering from a shortage of formally educated technicians. In the face of an expanding technology and the lack of qualified nondestructive testing technicians, manufacturers have attempted to satisfy these personnel problems by preparing training programs on their own initiative. Such practice has brought about numerous individualized programs, whereby complexity and confusion have often occurred in the inspection and evaluation processes when several manufacturers have supplied parts to the same contractor. Consequently, many misunderstandings between contractors have occurred over the effectiveness of the many different training programs. In turn, the quality of the inspected material has often been challenged. Verification of this challenge has been demonstrated by the numerous failures in engineered materials of ground and airborne functions.

Since World War II, the requirements for increased loads to be placed on structures have introduced many new materials which have accounted for much of the present advancement in technology. This relationship between materials and progress is pointed out by Fishlock when he stated, "Man's ingenuity and progress have always been allied closely to the materials at his disposal . . ." (4, p. 2). As quantity of engineering materials has increased, greater demands for soundness have likewise increased. This requirement for soundness has been reiterated by McMaster when he commented that the ". . . reason for the great growth in nondestructive tests is the designer's demand for sounder materials" (7, p. 1-6). A very reliable means used to verify soundness in a material is the ultrasonic test. This test is fast and accurate, but intricate equipment is necessary in locating flaws.

> Ultrasonics is a fast, reliable nondestructive testing method which employs electronically-produced, high-frequency sound waves that will penetrate metals, liquids, and many other materials at speeds of several thousand feet per second. Because ultrasonic techniques are basically mechanical phenomena, they are particularly adaptable to the determination of structural integrity of engineering materials (14, pp. 1-2).

Due to the expanding numbers of engineering materials and processes, the federal government in recent years, took steps, in the form of specifications, to cause uniformity in content and physical condition of manufacturing materials. These governmental requirements for increased quality control in manufacturing materials and processes precipitated several studies for the purpose of determining what, how, and how much should be inspected for quality assurance purposes. Implications from these studies have provided a strong degree of guidance in carrying out this research.

Organization of the Study

This study is organized into five chapters. Chapter I presents an introduction and overview of the study. Chapter II endeavors to illustrate the related literature and shows its significance and support to this study. Chapter III explains the procedures used to provide the information needed in accomplishing this study. Chapter IV presents an analysis of the data collected in this study. A summary, conclusions, and recommendations are presented in Chapter V. Also, implications for program planning in nondestructive testing and inspection are pointed out.

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CHAPTER II

RELATED LITERATURE

Introduction

American manufacturers and service companies have used all known methods of nondestructive testing in conducting their inspection operations. The manufacturer who produces parts to be highly stressed uses nondestructive testing, inspection, and evaluation throughout the manufacturing process. The service company provides nondestructive testing periodically for its aircraft, its trains, its ships, its trucks, and its fabricated structures. Because much of industry expects the ultimate capability from an engineering material, designers and manufacturers have been constantly on the alert for new ways to increase quality in a material.

In order to increase quality in a material and to obtain a valid evaluation of the material or an assembly of parts, it has often been necessary to perform several tests on the same material. Because some of these materials or parts are often complex in shape, the scope of testing possibilities becomes large. This magnitude has been industrially demonstrated in the utilization of several forms of energy during the many and varied testing procedures. An example of this magnitude is illustrated in Table I, which is an extract of a more comprehensive table by Hagemaier (1).

TABLE I

NONDESTRUCTIVE TESTING METHODS FOR MATERIALS EVALUATION*

Method	Measures or Detects	Applications	Advantages	Limitations
Sonic	crushed core	honeycomb	portable	standards required
Acoustic-Impact	cracked blade	turbine blade	simplicity	mass influence
Acoustic Emission	crack initiation	pressure vessel	portable	in operation
Penetrants	surface cracks	non-absorbing surfaces	low cost	clean after inspection
Magnetic Particles	cracks	magnetic materials	fast	demagnetize
Electrified Particle	cyclic cracks	glass	portable	high voltage discharge

*Extract from D. J. Hagemaier, Douglas Aircraft Company, California (1).

TABLE I -- Continued

Method	Measures or Detects	Applications	Advantages	Limitations
Radiography Gamma	internal cracks	inside places	film record	source decay
Radiography X-ray	porosity	castings	film record	radiation hazard
Radiography Thermal-Neutron	non-metal parts	biological	compliment	costly
Radiography X-Gamma-Beta	inclusions	tubing	fast	radiation hazard
Ultrasonic	cracks	welds	portable	couplant needed
Eddy-Sonic	crushed core	bonded metal	simplicity	standards required
Filtered Particle	cracks	sanitary ware	quick	skin irritation

TABLE I -- Continued

Method	Measures or Detects	Applications	Advantages	Limitations
Eddy Current	heat treatment	wire	low cost	penetration depth
Electric Current	cracks	train rails	D. C. source	edge-effect
Magnetic Field	hardness	treasure hunting	automation	edge-effect
Thermoelectric	coating thickness	sorting	simplicity	contaminants
Dielectric	thickness	glass-eopxy	portable	mixed variables
Thermal	heat transfer	brazing	simplicity	standards required
Thermal or Infrared	lack of bond	electrical	quantitative	costly

According to Hagemaier (1), most solid materials can be tested and inspected by one or more of the twenty methods shown in Table I. Even though many forms of energy are indicated, the table has been greatly simplified from the original in that only one example of use is shown for either detection of flaws, application of method, or to illustrate an advantage or limitation of the method. In regard to use, the number of situations appears endless; certainly, examples of use extend into the many hundreds.

Nondestructive testing seeks the true condition of a material; the operator and supervisor seek an ultimate evaluation of this condition. Even though the field of nondestructive testing is large, complex, and expanding rapidly, few studies in this area have been made to help unravel some of the growing complexities in quality control and production.

Because this study has been confined to Texas and because the junior college is implicated, the Texas Education Agency was contacted for information in regard to planned or accomplished research in nondestructive testing throughout Texas. According to the agency, no junior college in Texas has accomplished research or is planning research in nondestructive testing (8).

Most of the research accomplished in nondestructive testing has not been associated with educational institutions or professional organizations. The American Society for Engineering Education (4) has made no related studies in nondestructive testing. When queried, the American Society for Testing and Materials also made no reference to related studies made under their guidance (6). A limited quantity of information, however, came from the American Society for Nondestructive Testing, but this was mostly historical (5). The most important related study, Nondestructive Evaluation (10), originated from the efforts of the National Materials Advisory Board and is discussed in subsequent paragraphs with permission of the National Research Council (7).

Nondestructive Evaluation

The most comprehensive study ever made in the field of nondestructive testing, Nondestructive Evaluation (10), was conducted in 1967 by the National Materials Advisory Board for the National Academy of Sciences and the National Academy of Engineering in contract with the Department of Defense. This study was precipitated by a series of objectionable events throughout this nation which had caused great concern among those persons involved in nondestructive testing processes.

> The Committee which conducted the study reported herein took a broad view of the subject. It looked back over the years at the history of NDE, at the long-standing problems . . . at some unfortunate national [disaster], serious failures which have occurred and which, in good likelihood, might have been averted had an adequate NDE system been available (10, p. vi).

Several purposes of Nondestructive Evaluation were to ". . . determine critical areas in both the processing and operational phases . . . determine where present techniques are inadequate . . ." and ". . . stimulate the introduction of new concepts for major improvements . . ." (10, p. I-11).

In seeking attainment of objectives in Nondestructive Evaluation, the committee concluded that materials failure in military and civilian parts and components was due to many variables including a wrong concept of stress, poor design relative to strength factors, faulty manufacturing processes, and wrong use of materials (10, p. I-12). Further, the committee estimated that ". . . approximately 20% of today's recognized NDE problems have existed for ten to twenty years and are unsolved . . ." (10, p. I-12).

Past and present problems in nondestructive testing and inspection have been closely related to availability of skilled personnel. "An alarmingly small number of professionals are available to provide a cadre for the multidiscipline approach necessary to meet the objectives of increased design criteria and safety" (10, p. I-2). Therefore, the Department of Defense study recommended ". . . the implementation of appropriate graduate and undergraduate programs in NDE by making universities aware of DOD's needs through supporting contracts" (10, p. I-2).

Nondestructive Evaluation has repeatedly pointed out the circumstances which brought its study into being. One of the primary factors which developed unsolved problems in materials evaluation through nondestructive testing processes has been the increasing need to utilize all of a material's capability in order to profit from its strength-weight ratio. In deciding on how much of a material's capability to use, several wrong assumptions have often been made somewhere along the inspection process. One assumption has been that nondestructive inspection is conducted by skilled personnel. In reality, the literature has shown that the inspection operator oftentimes may not have been adequately skilled during the processing of critical parts. Flaws have frequently been unobserved. Consequently, when sudden loads have not brought satisfactory stress reactions in the material because of internal flaws, failure has occurred.

Due to the long absence of large numbers of qualified technicians, training programs have been prepared and executed in the many industrial plants and service companies throughout the United States with the objective of satisfying local production needs. Again, another assumption has been that these training programs were adequate. According to Nondestructive Evaluation (10), many of these programs have been inadequate in meeting the pressing needs related to increased design criteria. "Current educational courses for technicians are very inadequate. They range from a few days to six weeks in length. Practically no formal educational prerequisites are required; no tests are given, but certificates generally are issued" (10, p. II-2). Such assumptions by competent personnel and subsequent industrial practices precipitated an investigation into the numerous manufacturing processes where nondestructive inspections were made. The investigation led to Nondestructive Evaluation.

Industry and the federal government have long been closely tied to specification requirements in an effort to reduce unsatisfactory materials and subsequent material failures. Because of this close association much effort has been exerted to fulfillment of specifications and production of sound parts. However, compliance with specifications has pointed out the mounting problems in inspection techniques.

> The past two decades, particularly, have seen what has been popularly described as the 'materials explosion,' a burgeoning not only of improved materials of construction, but new concepts for materials . . . The simultaneous increased complexity of equipment and vehicle systems to meet the ever-demanding requirements of defense and space exploration has forced designers to attempt to exploit these new materials and techniques with greater sophistication and efficiency in their design approaches. In so doing, the designers have availed themselves of every possible technical contribution: new design concepts, materials at maximum strength with minimum flaws . . . Understandably, the ultimate users, desiring the best of all worlds, have compounded the problems by adding to their exacting functional and design requirements more stringent reliability constraints, to assure safety of personnel and mission (10, p. v).

In an attempt to reduce or eliminate many of the problems associated with manufacturing and material inspection, a few colleges have established educational programs in nondestructive testing. However, these programs are small in number compared to the nation's total educational needs in nondestructive testing. Table II reflects only nine institutions having a bachelor degree capability in 1968.

TABLE II

SUMMARY OF 4 YEAR COLLEGES AND UNIVERSITIES*

School	Full NDT	Partial NDT	Short Course	% if Partial	Usual Enrollment/Yr.			Class Laboratory	NDT Research
					Full	Partial	Short		
U. of Arizona	x				50			x	x
U. of Bridgeport		x		4		25		x	
Cal. State Poly.	x							x	
Carnegie Inst. Tech		x		5		40			
Chattanooga State		x		5		20		x	
Fresno State Col.		x		16		25			
U. of Hartford		x				60		x	x
Indiana State U.	x				10			x	x
U. of Iowa	x				15			x	x

*Information by courtesy of the ASNT, Liaison Division, Educational Council, Preliminary Report, March, 1968.

Used with permission of National Materials Advisory Board (7, p. II-12).

TABLE II -- Continued

School	Full NDT	Partial NDT	Short Course	% if Partial	Usual Enrollment/Yr.			Class Laboratory	NDT Research
					Full	Partial	Short		
Lehigh U.		x		5-10		25		x	
La. State U.	x		x		20		15	x	x
Lowell Tech. Inst.	x				20			x	
Mass. Inst. Tech.			x				40	x	x
U. of Mo. (Rolla)	x				50-100				
U. of Mo.		x		5-10		5-20			x
U. of New Ham.		x		5-10		20		x	x
Northeastern U.			x				50		
Ohio State U.	x	x	x	10	18	180	40	x	x
U. of Oklahoma			x						
Old Dominion Col.		x		20		60			

TABLE II -- Continued

School	Full NDT	Partial NDT	Short Course	% if Partial	Usual Enrollment/Yr.			Class Laboratory	NDT Research
					Full	Partial	Short		
Penn. St. (Beaver)			x				15		
Penn. State U.		x		10		25-70		x	x
Sacramento State	x							x	x
Stout State U.		x		10-15		20-30		x	
U. of Wisconsin			x				50		

The educational capability in nondestructive testing is even worse at the junior college level. Associate degree and specialized programs are in progress at the following institutions according to Nondestructive Evaluation (10, p. II-13): Brevard Junior College, Chattanooga State Technical Institute, Contra Costa Junior College, Erie County Technical Institute, Highline College, Milwaukee School of Engineering Institute, Temple University Technical Institute, and the San Diego Junior Colleges. Even though these colleges are producing varying types of nondestructive testing specialists, the national need for technicians is much greater than these colleges can produce, even with those technicians being produced through industrial training programs.

In addition to the efforts of the above institutions as stated by Nondestructive Evaluation (10, p. II-10), some limited nondestructive testing processes are being taught at these institutions: University of Washington, Drexel Institute of Technology, Illinois Institute of Technology, the University of Wisconsin, and the Milwaukee School of Engineering. The success of an educational program in nondestructive testing depends on large numbers of qualified personnel entering the field. This large production of technicians requires the efforts of many educational institutions. As new technicians take their places in industry, they are subjected to the changing demands of design and manufacture and are consequently forced to recognize and attempt to satisfy the changing needs. Therefore, education is continuous and infiltrates into all aspects of the testing and inspection cycles.

Because of the small number of educational institutions involved in nondestructive testing programs and in order to help alleviate the two-year technician shortage, Nondestructive Evaluation has described the function of the junior college with respect to this technical area.

> The technician level calls for an innate intelligence and aptitude. The minimum educational requirements should be a high school diploma plus training in such areas as equipment, procedures, electronics or related subjects. Two-year junior colleges or technical institutes could provide such formal education. On-the-job experience and/or apprentice training should be additional requirements. The combination of these two phases of education can then lead to the qualification and certification of NDE personnel along the lines described in the document, Recommended Practice No. SNT-TC-1A, published by the American Society for Nondestructive Testing (10, p. II-2).

The status of nondestructive testing, inspection, and evaluation programs requires enhancement at all operating levels and ". . . should profitably increase the interplay between the various disciplines, such as physics, chemistry, and materials science, which contribute heavily to and are involved in NDE" (10, p. II-4).

Conclusions drawn by Nondestructive Evaluation are shown in the following summary. These conclusions amplify the need for technicians.

1. Members of technical management, particularly those concerned with design, quality assurance, and serviceability of hardware are not fully aware of the rapidly-growing role of NDE in modern engineering and technology.
2. Generally, educational institutions do not have the interest, staff, or funds to establish and to staff the NDE departments needed to produce the people required by Government and industry. This dearth of capable personnel extends down through the technical level.
3. Individuals most knowledgeable in NDE are currently industrially trained engineers without Ph. D. degrees, generally unacceptable as faculty members by universities.
4. The shortage of qualified personnel at all levels cannot be alleviated without Government financial support to educational institutions (10, p. II-4).

Certain recommendations, emerging from the above conclusions, have been made by Nondestructive Evaluation. In effect, recommendations of the study have pointed out that the federal government must work with all levels of government and with educational institutions in order to produce ". . . the technicians, engineers, research scientists, and technical management necessary for our Government and industrial requirements" (10, p. II-4). These specific recommendations are pointed out:

1. Fund technical institutes and junior colleges to provide the laboratories and staff to train technicians.
2. Provide grants to universities to establish laboratories and staff for at least five years to assure continuity of programs.

3. Establish scholarship and fellowship grants, competitive in funding with those currently available to the sciences, to attract highly competent students to this new field at the undergraduate and graduate levels.

4. Stimulate personnel concerned with NDE to keep abreast of advances in technology (10, p. II-5).

Implications drawn from Nondestructive Evaluation (10) point directly at its conclusions and recommendations. Implementation of these recommendations rests with industrial and educational leaders and with their ability to understand the national need coupled with their willingness to take appropriate actions on the recommendations.

A Related Industrial Study

Based on a need to bring out some of the recommendations made by Nondestructive Evaluation, Tenney (14) in 1970 accomplished a review of the comprehensive study. As stated by Tenney (14), "The tremendous progress made by materials science and engineering during the last quarter century is, indeed, unprecedented in the history of mankind" (14, p. 11A).

The introduction of these new materials for supporting structures along with the new concept in design brought additional demands in nondestructive testing, inspection, and evaluation. Experience has shown that design and material, once merged, must carry out their functions according to expectations and must also be able to ". . . withstand extreme internal and environmental forces, whether they be of mechancial or chemical nature, or caused by various forms of radiation" (14, p. 11A). This concept was recognized by the Department of Defense.

> It is, therefore, not surprising, but at the same time commendable, that the Department of Defense requested in 1967 that an in-depth study be made not only on the state of the art of nondestructive testing, but also its shortcomings, its potentialities and various means to improve its implementation and integration into the entire gamut of today's and tomorrow's technology, design, engineering and production criteria and concepts (14, p. 12A).

Conclusions drawn by Tenney (14) in his review of the Department of Defense study point out the inability of educational institutions to keep in step with the new technology demands in nondestructive testing, inspection, and evaluation. Specifically, ". . . educational programs . . . are highly needed to cover . . . a) the technician level, b) the engineer level, c) the research scientist level and d) the technical management level" (14, p. 13A). A final recommencation brought out by Tenney declares

> . . . that American universities must be convinced that nondestructive evaluation is a science relying upon the most advanced knowledge in fields such as physics, materials and electronics. Once the preliminary goal has been reached, it is then hoped that these institutions realize the importance of incorporating this subject into their curricula and to produce well-qualified and greatly needed NDE engineers (14, p. 13A).

With respect to qualified engineers, there is also the need to qualify the technician, as was pointed out in the

Department of Defense study. It is the technician who supports the engineer and in fact, does some of the work of the engineer. In his final comment regarding Nondestructive Evaluation Tenney indicated:

> If materials are to be designed to their limits to satisfy the ever-increasing demands of sophisticated engineering systems, it is necessary that nondestructive evaluation be deliberately considered for incorporation into every phase of the design-production-service cycle (14, p. 16A).

Education is part of the design-production-service cycle.

Implications from Tenney's study strongly recommend that educational institutions organize and implement programs in nondestructive testing, inspection, and evaluation as soon as practical in order to alleviate the shortage of skilled personnel in this expanding field.

The Fourth International Conference of Nondestructive Testing

Prior to the federal government's attempt to provide uniformity and comprehensiveness in local inspection programs, delegates from around the world met in London, England, for the purpose of examining the whole area of nondestructive testing and inspection. This meeting in 1963 was the Fourth International Conference of Non-Destructive Testing. These specialists from twenty-eight nations exchanged their ideas and presented new information in hopes of reducing the growing number of inspection problems. According to the President of the Conference, H. N. Pemberton,

". . . the value of these conferences is to be found in the exchange of information and the discussions of the progress made in development and application of non-destructive testing techniques" (12, p. 350).

Even though valuable information was exchanged at the conference, some question concerning the importance of formal education was exhibited by a conferee, G. A. Homes, who stated: ". . . we must give, in universities and engineering colleges, a minimum of lessons to every student concerning non-destructive testing, but for making specialists, I believe it is better to give post-graduate courses . . ." (12, p. 351). In view of this remark little concern was shown for the technician, especially the two-year technician. However, within a short period of time, much of the information learned at the conference was planted in American industry. Certainly, this conference was not the cure for confusion in manufacturing, pertinent to nondestructive testing, as evidenced by the Department of Defense study Nondestructive Evaluation, which was conducted within the next four years.

Recent Development of Formal Training Programs

Another study of nondestructive testing in industry was made by Pade (11). In this study he found that prior ". . . to 1960, most NDT training and examining programs were conducted on an informal basis. Only a limited number of documents . . . requiring formal NDT personnel certification procedures existed" (11, p. 23A). This indicates that the present formal training programs within industry have been developed mostly within the past decade. Also, this current formal training program situation was pointed out by Mills (9) back in 1962 when he remarked: "Nondestructive testing is behind the technological level of design, fabrication, and production; intelligent, concentrated work is needed to close this gap" (9, p. 8). Because some areas of the inspection part of industry have grown faster than others, a technological lag exists between material inspection equipment and technicians available to operate it.

Related Technological Studies

Vasek (15) made an investigation in 1967 throughout several of the southern states in an attempt to find the effectiveness of post-high school technical programs which included offerings in electronics. The study endeavored to determine if industry's needs were being met through the results of these programs. An objective of his study sought a relationship between the electronics offerings in school and needed knowledge and skill in industry. Also, the study endeavored to determine the amount of emphasis that should be placed on selected items of subject matter so that proper consideration could be given to these subjects in the formulation of a program.

The Vasek (15) study incorporated an industrial survey to obtain information needed in qualifying electronic technicians. The survey instrument was a questionnaire which consisted of a rating scale and a listing of instructional items peculiar to electronics. The rating scale was accomplished by selected respondents in industry and in school. Results showed the following information:

> Of the 435 units of content analyzed, 72.6 percent were taught in depth and 27.4 percent were discussed briefly. Industrially, 20.5 percent of the content was required knowledge, 77 percent was preferred knowledge, and 2.5 percent was considered unnecessary knowledge. There was educational and industrial agreement on the amount of emphasis placed on 45.3 percent of the electronic content. In the remaining 54.7 percent of the instructional units, educators placed more emphasis on content than industrial personnel believed necessary (15, p. iii).

Conclusions of the Vasek (15) study indicated that instructor personnel placed more emphasis on instructional matter than was considered necessary by industry. Therefore, a recommendation was made that future electronic curricula be formulated to meet industrial needs. Implications from the study have indicated the importance of educational institutions coordinating their educational efforts with industry prior to organizing a technical program. Even though a small percentage of subject matter was considered unnecessary in meeting industry's needs, the study pointed out a significant disagreement between industry and educators in regard to subject matter being taught.

A similar study was made by Wright (16) in 1969. Using a comprehensive questionnaire based on electronic subject matter units, he conducted a survey of Texas industrial plants, research agencies, junior colleges, telephone companies, and broadcasting stations. A purpose of his survey was to obtain the necessary degree of emphasis which should be placed on each item of subject matter for the purpose of formulating the information into an electronic program. Procedure followed by Wright (16) was closely related to Vasek's (15, p. 5).

> The purpose of Vasek's study was to identify the units which should be included in the electronic technology curriculum in the Southeastern United States, and to determine what teaching emphasis was thought necessary for each unit by electronic-related industries and by teachers in electronic technology programs (16, p. 14).

Proceeding along a similar approach made by Vasek (15, p. 14), Wright (16) prepared a four column rating scale for rating the necessary degree of emphasis to be placed on each item of subject matter; Vasek had used a three column emphasis scale. The hypotheses stipulated by Wright (16) were related to Vasek's in that both investigators indicated that no major differences existed between degrees of emphasis to be placed on instructional units in electronics. According to Vasek, "The hypothesis to be tested was that no major differences existed between electronic course content offered in technical institutes and subject matter required of electronic technicians" (15, p. 3).

Hypothesis number two of Wright's study stated, "There will be no significant difference in the degree of teaching emphasis indicated necessary for each instructional unit by raters from among the different industries" (16, p. 7).

A conclusion of the Wright study is quoted:
"1. Representatives of the industries participating in this study were not in agreement concerning the degree of teaching emphasis which should be given certain units" (16, p. 126). In this respect, Vasek (15) also found disagreement among rating personnel. He had recommended that instructional personnel and industrialists coordinate their efforts prior to formulation of a curriculum. Likewise, Wright (16) had recommended that educators and industrialists coordinate instruction in electronic technology in order to better meet the needs of industry. Because Vasek (15) and Wright (16) found disagreement in the relative importance of subject matter in electronic technology by both educators and industrialists, implications point toward closer coordination between industry and schools when technical programs are being planned.

Jordan (3), in 1969, completed a study in industry to determine relative subject matter which could be used in planning a computer technology program. Results of his survey found at least one half of the respondents marked items of subject matter as being important with reference to understanding the use of the computer. In 1968, Heggen (2) concluded from his study of the aptitudes and achievements of students at the Utah State Industrial School that guidelines existed for formulating a program in vocational education. Another study was based on conflicting data pertaining to the role of the chemical technician in industry. Sandberg (13) conducted a survey for the purpose of determining needed knowledge, duties, and skills of the chemical technician. Conclusions indicated that at all levels of skill the technician assisted the engineer and that industry's needs were of primary importance.

Summary of the Literature

The literature pertaining to nondestructive testing and inspection has been in strong agreement that action be taken to educate more nondestructive testing technicians for the growing manufacturing field. Further, the literature has emphasized the importance of educating large numbers of technicians in order that industry will not be stymied in technological progress.

Because educational programs in nondestructive testing are very expensive, the literature has shown that much of the initial expense in setting up programs could be absorbed by the federal government. In this respect, a point of interest was pointed out whereby educators should recognize the growing need for technician training and take action to organize and implement programs.

Recommendations have been made to initiate programs in nondestructive testing, but little effort has been made to provide educational guidance. Therefore, an objective of this study is the formulation of a two-year junior college program in nondestructive testing, inspection, and evaluation.

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CHAPTER III

PROCEDURES

The purpose of this study was to survey selected Texas industries and service companies with the objective of obtaining adequate information for use in formulating a two-year junior college program in nondestructive testing, inspection, and evaluation of engineering materials.

The procedural phase of this study was divided into several parts. To begin with, technical data had to be gathered from several sources in order that it could be studied for subsequent use in the survey instrument. Gathering technical data included the attainment of information from certain manufacturers relative to nondestructive testing equipment capabilities and functions. Following this phase of study, an attempt was made to procure names of companies and individuals in Texas to serve as a sampling population for the future survey. Along with these parts of the study, personnel in industry were interviewed with the objectives of obtaining additional technical data, operational information, and more names for the mailing list. As a result of these initial steps, a questionnaire was constructed.

Following the development of the questionnaire, a sampling population was identified. Subsequent procedures provided a representative sample which was used in hypotheses testing and program planning.

Gathering Data for the Study

The nature of nondestructive testing is technical and reaches into many areas of knowledge. Consequently, a primary concept of data expectations was needed in order to proceed with the study.

First, it was realized that equipment had to be studied and evaluated. It was also realized that nondestructive testing equipment is varied in design and some complex in use. In addition, equipment data had to satisfy the five main areas described in this study. With these equipment need factors in mind, letters were mailed to manufacturers of nondestructive testing equipment requesting their assistance in the procurement of this information. The results of the requests for information were very satisfactory.

The next step in the equipment data gathering phase was the obtaining of names of users of this equipment for the purpose of identifying a sampling population. Consequently, subsequent letters sent to many of these same equipment manufacturers requested names and addresses of testing companies in Texas who were using this equipment. The results provided only a few names. A sample of this letter is shown in Appendix A.

Next, it was realized that a curriculum was needed in formulating a nondestructive testing and inspection program of instruction. The curriculum would result from a questionnaire. Therefore, information received in the early parts of this study was integrated into a questionnaire, Appendix H, and mailed to selected manufacturers and service companies in Texas for accomplishment and return.

Interviewing Personnel

Interviewing was conducted with industrial personnel concurrently with the equipment information part of the study and in conjunction with the survey processes. One of the main objectives of the interview was to seek key elements from all phases of nondestructive testing for incorporation into the questionnaire.

Another objective of the interview was to investigate the scope and effectiveness of local industrial training programs in order to assure that this aspect of the study was considered when the questionnaire was being constructed. The results of this investigation revealed many programs planned to conform with equipment on hand. Most programs were confined to a designated number of clock hours with the aim of proficiency attainment in specialized subject matter.

Along with the investigation of training programs, selected questions were asked in an attempt to procure data for a later part of the study concerning safety factors, materials, space, housing, costs, procedures, special equipment, objectives, and expected proficiencies from operators. Further, members of professional societies were queried with respect to training needs and were also questioned about the long range employment outlook in nondestructive testing.

Another very important objective of the interview was to obtain names and addresses of individuals who could possibly participate in the study. As a result of these interviews, requests for participation were received.

Constructing the Survey Instrument

Because nondestructive testing involves the use of many forms of energy and ranges from the simple to the complex in its scope of testing procedures, it was deemed that the questionnaire should be as comprehensive as possible. Basically, the instrument consisted of a listing of pertinent subjects which were to be rated for relative importance by specialists in the field. It was known that complete coverage of the main subjects in the testing and inspection areas was essential in order for the future instructional program to be meaningful in its procedures, objectives, and challenges. In this respect, the subject matter also required validation by a panel of judges prior to dispatch to the respondents. Therefore, information obtained in previous phases of this study was analyzed and arranged into key elements of subject matter in each of the five main areas of nondestructive testing. These key elements were then placed in column form so as to portray an outline of related subject matter. Part of the outline is shown in Appendix B.

Even though a listing of key points of subject matter pertaining to all main areas of nondestructive testing was finally constructed into an outline, there was still the necessity to ascertain the relative importance of each subject. With this factor in mind, it was decided that a certain degree of emphasis could be placed on each subject by a skilled rater in industry and this rating would then reflect the degree of importance to be given the subject by an instructor. Consequently, it was seen that the arrangement of subject matter shown in Appendix B would later be assigned some form of numerical rating. This arrangement is shown in Appendix C. Appendix C indicates the degrees of emphasis as they were initially arranged in formats for the judges' consideration and then as they were arranged in final form following the judges' consideration.

Even though a degree of emphasis was established for each different subject in the outline, it was also necessary to associate a time factor with a degree of emphasis. These time factor arrangements are shown in Appendix D. The revised format provided a means for checking a column to show the amount of time needed in teaching each different subject. After revising the emphasis and time columns, consolidation with the subject outline was effected. The completed arrangement of the final form of this part of the questionnaire is shown in Appendix E.

After completing the format for the main part of the questionnaire, each area of testing was reviewed to assure that all important subjects in the testing areas were covered with respect to operational functions. Due to manufacturers and service companies performing different processes in a testing area, a functional capability for these companies was also included. Because the questionnaire provided a rating scale on subject matter, different raters had a choice in rating the subjects as they saw it. The two most competent groups of persons to accomplish the ratings were operators and supervisors. Since operators and supervisors frequently have different perspectives in their viewpoints of testing activities, a functional capability for each of these persons was provided. In essence, the constructed instrument provided a four-way capability to handle most inspection problems in the field of nondestructive testing. The four-way capability included rating provisions for the manufacturer or service company and the supervisor or operator.

In addition to rating the importance of subject matter, it was necessary to obtain information concerning other areas of nondestructive testing. To accomplish this, the latter part of the questionnaire was provided with specific questions and spaces for responding.

When viewed as a whole, the tentative questionnaire consisted of the following main elements:

1. Identification of the respondent with respect to

his being associated with either a manufacturing or service company. No names of respondents were requested.

2. Identification of the respondent with respect to his being either a supervisor or an operator.

3. Directions for completing the questionnaire.

4. A check list for checking the degree of emphasis that the respondent felt should be placed on each of the 262 items of subject matter.

5. A check list for checking the length of time that the respondent felt was necessary in discussing each technical subject.

6. A series of pertinent questions to be answered by means of a check mark or by means of short answers.

7. A series of pertinent questions to be answered by only one person representing the company in the event more than one person received questionnaires in the company.

8. A space for indicating desirability of receiving a summary of the study.

Instrument Validation

The next step in the questionnaire accomplishment phase included a comprehensive review by a jury of six judges. In order to accomplish this task, the field of nondestructive testing and inspection was searched; six judges were found and were requested to serve as a jury, Appendix F. These judges were chosen because they were professionals in the field. They agreed to perform the task of validation.

Each judge was then sent a copy of the questionnaire for the purpose of review and approval. A copy of the letter to the judges is shown in Appendix G. They were requested to delete, change, or add subject matter or other information as they thought proper. In these respects, it had been previously established that agreement among four of the six judges would constitute validity of the instrument. After two weeks of deliberation, the six copies of the validated instrument were returned. Only a few minor changes were suggested.

The suggested changes were reviewed and approved. When all changes had been completed, reproduction of the final version of the questionnaire, Appendix H, was accomplished and then made ready for mailing to the sampling population.

Identifying the Population

Up to this point in the study, only a small number of names and addresses had been secured to serve as the initial population from which the sampling population would be obtained.

In other words, all efforts to obtain a large and suitable mailing list had failed. Consequently, other procedures were considered such as contact with professional organizations. A letter was then immediately sent to the American Society for Nondestructive Testing requesting its assistance in obtaining a mailing list. The society's answer (9) suggested a means for adding more names. Another chance effort included a review of the Standard Industrial Classification Manual (13), published by the United States Government Printing Office. Little success, however, was attained in this procedure. Nevertheless, the manual contained a reference to state publications, and it was this reference that led to the discovery of the 1970 Directory of Texas Manufacturers (2), (3). The two volumes of this directory were closely screened. Results were very favorable in that a large number of diversified manufacturers' names were added to the mailing list.

Because a large number of addresses were available from the directory, it was necessary to use a selective approach in earmarking company names. After some study of the directory's organization, it was decided to use the following classifications or major groups indicated in the directory to provide a list of manufacturers and service companies:

13 Products Recovered from Natural Gas

19 Ordnance and Accessories

28 Chemicals and Allied Products

29 Petroleum Refining and Related Industries

33 Primary Metals Industries

34 Fabricated Metal Products, except Ordnance, Machinery, and Transportation Equipment

36 Electrical and Electronic Machinery, Equipment, and Supplies

37 Transportation Equipment

38 Professional, Scientific, and Controlling Instruments; Photographic and Optical Goods; Watches and Clocks

Several hundred names were extracted from the directory. An important point, however, in this respect, pertained to the brief description of the company's functions. In other words, the directory reflected no information about a company performing nondestructive testing; therefore, the names and addresses extracted from the directory were potential users of the testing equipment because company names were described only as manufacturers of certain kinds of materials, parts, or equipment. Consequently, it was necessary to use clues shown in the directory in earmarking company names for the initial population.

An explanation of the inference process used in detecting possible users of nondestructive testing equipment is presented in order to illustrate how a suitable population was finally obtained. Because most manufacturers use some kind of quality control in maintaining acceptable standards of production, an inspection process is therefore required prior to delivery of the item.

Often, the inspection process utilizes nondestructive methods in helping to assure control of quality in the item. As an example, if steel were cast and subsequently rolled by a company listed as selling structural steel, nondestructive testing was probably performed because heavy castings and many rolled products often utilize some type of nondestructive testing in quality control procedures.

With respect to quality control, Hansen has indicated that "To an enlightened management it must represent a business investment which, as any other investment, should show a proper return to justify its existence" (7, p. 1). This definition refers to some kind of inspection process. The definition served as a guide in reviewing the listing of names.

Quality control procedures which are used in steel casting and rolling processes examine the product for flaws such as inclusions. According to Campbell, "Any separate undesirable foreign material present within the metal of a casting is known as an 'inclusion'" (4, p. 208). An inclusion often reacts under load as a crack and failure has frequently occurred in the otherwise acceptable material because of the tiny foreign mass. Therefore, the material is tested in a search for inclusions. The test is nondestructive. The kind of part produced is the clue. The part's general description or its use then served as the primary means for identifying the manufacturer.

Another example is illustrated by Edgar, who pointed out that ". . . products which are related directly to public safety must receive much closer attention in these matters than those which are only remotely connected to it" (5, p. 13). Again, a strong implication is present, the airplane being a prime example. And Parr has emphasized that "The strength of a metal is a measure of its capacity to resist forces imposed upon it under given conditions" (10, p. 32). Under load, force or stress detours around the inclusions, making a stress raiser which provides the situation for metal failure through separation. Consequently, a study of the products produced by a manufacturing company brought implications into being, and through these implications, a large number of names were added to the mailing list.

After completing this procedure a study of the list was again accomplished. A review showed few airlines and engineering testing laboratories using nondestructive testing. In order to obtain names of these companies, telephone books of several large Texas cities were reviewed. Results of this procedure supplied a generous mixture of potential users of nondestructive testing processes.

Sample Size and Population Representation

Several assumptions regarding sample size were made prior to conducting the survey. Because the hypotheses of this study would be tested by the chi-square formulas for independence of samples, a minimum of fifty representative samples was needed. The chi-square procedure provides a mathematical value that indicates whether or not a significant relationship exists between two variables as a result of a dependent variable. Sax has indicated that "Chi-square is used to test the significance of the differences between a set of observed frequencies and a set of frequencies expected on the basis of a hypothesis concerning some population" (12, p. 422).

For purpose of clarity, the Chi-square formula is stated: $\chi^2 = \frac{(O-E)^2}{E}$. Chi-square is generated as the summation of the square of the observed frequencies minus the expected frequencies divided by the expected frequencies. Chi-square then points out the significance of the sample's response at a certain level of confidence.

The sample's size must be large enough to be meaningful. According to Roscoe,

> there is no restriction with respect to the number of categories when the chi-square statistic is used in tests of independence; however, there is the limitation with respect to sample size. Generally, the use of the chi-square statistic requires rather large samples . . . (11, p. 196).

Roscoe has further described sample size by pointing out, "The use of samples of size 30 or larger usually insures for the investigator the benefits of the central limits theorem . . ." (11, pp. 156-157).

A further investigation into sample size shows, according to Fox, "The question of how large a sample should be is basically unanswerable, other than to say that it should be large enough to achieve representativeness" (6, p. 346). Fox has also pointed out

> . . . the fact that the statistical dividing line between large and small samples is a sample size of 30 . . . if we wish to have what will statistically be considered large samples, we will want to have at least 30 in each of two samples, or 60 in one sample (6, p. 347).

Obtaining adequate numbers of samples from the population has often been a difficult task. Fox has dramatically remarked that low returns ". . . occur with disheartening frequency" (6, p. 348). He also indicated that if the investigator ". . . plans to use data-gathering instruments which will be mailed to the accepting sample, then he will find that serious attrition is a very real threat, for returns of 30 percent are common . . ." (6, p. 348). The percentage of return factor was given serious thought in deciding on the needed size of the initial population to sample. This return factor has been described by Fox when he referred to the researcher in establishing a population size: "He should then select a sufficiently large and diverse sample so that even if serious attrition occurs, he still has a sufficiently large data-producing sample to have the basis for a reasonable study" (6, p. 348).

Another researcher, Hillway, has additionally pointed out, "In general, the larger the sample . . . the higher its degree of reliability . . . both size and representativeness of the sampling have an important bearing on the results . . ." (8, p. 185).

Best has also described the sample in regard to its significance:

> When data are classified into categories representing distinctive characteristics, the operation of the laws of probability might account for some of the cases that fall into each category. It is important to know whether these proportions merely reflect the operation of chance, or whether their appearance probably results from a significant controlling factor (1, p. 227).

When the above comments from researchers and statisticians were evaluated, it was concluded that 100 samples would satisfy the requirement of representativeness and at the same time provide sufficient data for hypotheses testing. Also, 100 samples would provide the additional data needed to project a trend in the need for nondestructive testing technicians, and would furnish other required information.

Because of the possible attrition factor and because of uncertainty in knowing which companies were performing nondestructive testing and not knowing those which would be willing to participate, an initial population of 547 manufacturers and service companies was chosen and established from which to identify the sampling population. This 547 figure represents the functional cross-section of Texas industries and service companies as indicated in Appendix I. Fifty-nine distinct categories of business enterprises are shown in this listing. Geographical representation is illustrated in Appendix J. Most of the samples were represented in two heavily concentrated industrial areas, Houston and Dallas-Fort Worth.

Accomplishing the Survey

As soon as the initial population of 547 business concerns was chosen, the survey commenced. Contact with the manufacturer or service company was made by first class mail. Enclosed in the letter to the respondent was an introductory letter, Appendix K, with an attached form, Appendix L. A self-addressed stamped envelope was also enclosed. North Texas State University letterhead stationery and envelopes were used in written communication to the respondent.

The introductory letter explained the purpose of the survey and asked the person receiving the letter to respond to the request for participation in the survey by completing the attached form and returning it. Of the 547 letters mailed, 249 forms were returned, each indicating one or more persons who would participate in the survey or indicating that participation would not be made. A review of the forms showed that ninety-six requested participation in the study. Because each form included one or more names of persons desiring to participate and because other requests were received by separate letters, a total of 276 requests for participation were received. These individuals then became the sampling population.

Upon receipt of request for participation, another letter, Appendix M, was mailed to the respondent. Included in this letter were the letter thanking the respondent for participation, the questionnaire, and a self-addressed stamped envelope. It was hoped that each respondent would then complete the instrument and return it within a two-week period of time.

Three separate attempts to retrieve the questionnaires were made. At the end of the first two weeks period following commencement of the survey, 154, or 55.7 per cent of the questionnaires had been returned. Those respondents who had not returned their questionnaires within approximately two weeks were sent another letter, Appendix N. The second attempt to obtain overdue questionnaires brought in another thirty-nine, this being a 69.8 per cent return.

Because the survey was limited in time, a cut-off date of May 19, 1971 was established. A third letter was then sent to those respondents, Appendix O, who had not yet returned their responses. The last attempt to retrieve all questionnaires brought in another five, constituting a final 71.7 per cent return.

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CHAPTER IV

ANALYSIS OF DATA

Introduction

Upon completion of the survey, analysis of the data commenced. These data were obtained from many sources in Texas industry and included a mixture of personnel representing manufacturers, service companies, supervisors, and operators. This mixed population was essential in providing a background for testing the hypotheses. In addition to testing the hypotheses, other data were received for program planning.

A total of 198 questionnaires were returned as the result of the survey. Of these 198 samples, seventy were too incomplete for testing the hypotheses; however, they were suitable for use in a total evaluation of the study. The remaining 128 reflected possibilities for use in all aspects of the study. A review of these returns showed representation from sixty-three manufacturers, sixty-five service companies, sixty-seven supervisors, and sixty-one operators. Appendix I lists the types of companies represented and Appendix J indicates the approximate geographical locations of these companies. The business concerns listed in Appendix I reflect participation from major industrial areas.

Hypotheses Testing

Three hypotheses were tested in support of this study and are stated:

1. There will be no significant difference in emphasis placed on each selected subject by personnel from manufacturing and service companies who are engaged in nondestructive testing and inspection processes.

2. There will be no significant difference in emphasis placed in major areas of subject matter by personnel from manufacturing and service companies who are engaged in nondestructive testing and inspection processes.

3. There will be no significant difference in emphasis placed on each selected subject by nondestructive testing and inspection supervisors and operators.

Prior to testing procedures, the 128 samples were examined to assure that all subject items had been checked by respondents. An examination revealed that some samples contained omissions. Most of these omissions were in Column 1 and when totaled, the population's response for Column 1 indicated 1.9 per cent of the total response. This response is indicated in Appendix P. The per cent factor in all subject items listed in Appendix P is not greater than 5.5, except the requirement for "lasers," which was rejected by 8 per cent of the respondents. Consequently, the small number of responses shown in the first column did not justify the column's retention.

Because a close relationship existed between "No need to be discussed" (Column 1) and "Discussed briefly" (Column 2), it was decided to collapse Column 1 and merge it with Column 2. This merging of related data was recommended by Roscoe when he pointed out, "In order to meet the criterion of 80 per cent of the cells having expected frequencies of five or more, it is necessary to collapse the adjacent cells where the frequencies are low" (1, p. 200). This method of collapsing cells is further reiterated by Sax when he explained, ". . . if the expected frequencies are less than 5, the chi-square table should be 'collapsed' to include fewer numbers of cells and larger expected frequencies within each cell" (2, p. 423). A value of 1, the lowest value, was then recorded in all columns where check marks had been omitted in order to provide a number in each cell of the formulas. Questionnaires containing more than 8 per cent omissions were not used in hypotheses testing.

In order to proceed with hypotheses testing, the services of the computer at North Texas State University were used. Because the survey instrument was now a three-column arrangement of subject matter, a two by three bivariate contingency table was selected in testing. Roscoe described the purpose of the bivariate table when he stated that ". . . the statistical test is made to determine whether classification on the row variable is independent of classification on the column variable" (1, p. 196).

A two by three bivariate table has two degrees of freedom while the "N" value for the table was calculated to be 128 for Hypotheses I and III. When a .05 level of significance was used, the Chi-square Distribution Table showed that a value of 5.99 was needed to reject these hypotheses.

Appendix Q presents the test results for manufacturers and service companies after testing was completed. An examination of this appendix points out those subjects which were retained and rejected in accordance with Hypothesis I. The respondents were not in agreement with twenty-four subject matter items. This means that the hypothesis was rejected for these items. The remainder of the subject matter items showed agreement among respondents, indicating retention of the hypothesis for these items.

An analysis of the rejected items points out that in three instances, relative importance of the operator's ability to use the equipment was not agreed upon by the respondents. Also, the test results reflect agreement by all respondents in the main area of magnetic particle testing. Four subjects in the penetrant method were in disagreement, while only three subjects in the eddy current method showed disagreement. In ultrasonics, ten subjects were in disagreement, while seven subjects indicated disagreement in the radiographic method. Lastly, one of the most important subject items in ultrasonics, "Size of defect determination," showed disagreement.

Appendix R shows the results of the tests for supervisors and operators and also points out those subject matter items which were retained and rejected in accordance with Hypothesis III. The Appendix indicates that nineteen respondents were not in agreement with the specified subject matter. Therefore, Hypothesis III was rejected for these subjects while the remainder of subject matter was approved.

A review of Appendix R points out five subject items in the penetrant method which showed disagreement. Also, five subjects were in disagreement in the magnetic particle method even though all respondents agreed upon these items as pointed out in Appendix Q. Only three subject items in ultrasonics showed disagreement, while two were in disagreement for eddy current. Lastly, four items portrayed disagreement in the radiographic method.

A consolidation of rejected subject matter shown in Appendices Q and R is listed in Appendix S. A total of forty-two subjects are indicated where disagreement existed between manufacturers and service companies and between supervisors and operators. Only one subject, "Operator's ability to use eddy current testing equipment," was rejected by both the manufacturer-service group and the supervisor-operator group.

The test results of Hypothesis II are indicated in Table III. Hypothesis II stated that there would be no significant differences in main areas of subject matter according to replies of personnel from manufacturing and service companies.

TABLE III

SIGNIFICANCE OF MAJOR AREAS OF SUBJECT MATTER
ACCORDING TO RESPONSE DATA

Subject Matter	No.	Category*	Hypothesis	
			Retain	Reject
Penetrant	41	x		x
Magnetic Particle	51	x		x
Eddy Current	55	x		x
Ultrasonic	56	x		x
Radiographic	41	x		x
Total	244	x		

*Manufacturer and Service Company.

According to Table III, there was a significant difference in emphasis placed in all main areas of subject matter indicating that the total population was not in agreement with the relative importance of the subject matter items. The five main areas totaled 244 separate subjects. The table indicates the number of subjects within each main area.

The "Degree of Emphasis" columns listed in the questionnaire were next reviewed in order to determine the responses of the population. An examination of these columns points out a heavy concentration of responses in Column 3. The total results of responses are indicated in Table IV.

TABLE IV

POPULATION'S RESPONSE SHOWING DEGREE OF EMPHASIS

Degree of Emphasis		
Column 1 - 2	Column 3	Column 4
Discussed Briefly	Discussed in General	Discussed in Detail
Per Cent	Per Cent	Per Cent
26.5	41.0	32.1

Table IV indicates that of the 244 items of subject matter listed, 41.0 per cent were marked to be discussed in general. Nearly one-third, 32.1 per cent, were marked to be discussed in detail, while 26.5 per cent were marked to be discussed briefly. The table indicates that approximately 75 per cent of the subject matter should be discussed to a greater degree of emphasis than just briefly.

Recommended Time to Be Spent in Teaching Subject Matter

The "Time" column in the questionnaire indicated the length of time needed in teaching the 244 subjects. The purpose of this column was to add emphasis to the "Degree of Emphasis" column. In other words, when both "Degree of

Emphasis" and "Time" columns were checked, a more positive indication resulted as to the importance of the subject. Results extracted from the 128 questionnaires are noted in Appendix T. For each time column, and for each subject listed in Appendix T, there is a value showing the number of respondents who checked the specified columns. Also, the number who checked each column was converted to a percentage value. Most respondents indicated that less than two hours were sufficient to discuss the individual subject items.

General Education

Eighteen subjects in general education were included in the Questionnaire, Appendix H. Sixty-three manufacturers and sixty-five service companies participated in this phase of the nondestructive testing study. The four degrees of emphasis are shown in Table V for each subject as they were checked by the respondents.

An analysis of Table V shows that all respondents indicated a need to discuss "Oral Communication" and "Quality Control." Only three respondents believed that "Safety Precautions" were unimportant. All subjects, however, were checked by a small percentage of respondents in the "No need to be discussed" column, except "Oral Communication" and "Quality Control." All other subjects were checked as being necessary to some degree. Table V shows that the emphasis on subject matter is greatest in Column 3; therefore, a general discussion was emphasized.

TABLE V

RESPONSE TO DEGREE OF EMPHASIS IN GENERAL EDUCATION

Subject	No Need to Be Discussed		Discussed Briefly		Discussed in General		Discussed in Detail	
	No.		No.		No.		No.	
	M	SC	M	SC	M	SC	M	SC
F 1	0	0	9	15	28	35	26	15
F 2	1	2	9	12	23	34	30	17
F 3	2	0	7	21	29	31	25	13
F 4	2	1	14	21	32	30	15	13
F 5	1	1	8	19	32	32	22	13
F 6	4	2	11	19	25	31	23	13
F 7	4	0	13	23	26	33	20	9
F 8	1	1	16	19	28	33	18	12
F 9	1	4	15	20	29	30	18	11
F 10	0	0	4	7	29	28	30	30
F 11	3	6	15	18	30	30	15	11
F 12	4	4	17	20	32	36	10	5
F 13	2	1	9	14	25	30	27	20
F 14	2	0	6	13	22	26	33	26
F 15	1	1	11	10	24	29	27	25
F 16	1	0	9	7	21	23	32	35
F 17	2	1	12	6	23	27	26	31
F 18	3	0	0	0	20	20	40	45

Additional Subject Matter

Even though a comprehensive listing of subject matter for the proposed program was provided, Appendix H, several additional recommendations were received. The questionnaire had made provision for this possible addition. An examination of Appendix U shows eighteen recommended subjects to be added to the proposed program in nondestructive testing and inspection. These subjects refer mainly to automated possibilities and to refinement of existing processes in the field of nondestructive testing. However, many respondents pointed out the special need for safety during the processes of testing and inspection. Different chemicals and high voltage electricity are used in many situations which may account for their interest in safety.

Importance of Phases of Nondestructive Testing

The Questionnaire, Appendix H, had provided another means for increasing the effectiveness of the proposed training program by requesting respondents to indicate their answers to the questions shown in Table VI. There are four questions shown in this table associated with provisions for checking the importance of applicable phases of nondestructive testing. For purposes of clarification in reading the table, these questions are stated:

1. Do you believe the technician should be proficient in all phases of NDT or in one or more phases?

2. Which NDT phases appear to be growing into more usage?

3. Which NDT phases have more applications in your area?

4. Which NDT phases do you believe should be supported with additional research?

In response to Question 1, 85.3 per cent of the respondents indicated that all phases of nondestructive testing were important in attaining proficiency. The least important phase for proficiency attainment is shown as eddy current due to 6.5 per cent of the respondents having checked this phase. Question number 2 was checked as ultrasonic with a 65.1 per cent response indicating that ultrasonics is growing into more usage than other phases. The least growing phase of nondestructive testing, penetrant, was checked by 10.1 per cent of the respondents. Question number 3 pertained to the respondent's work. Radiographic was checked by 43.9 per cent, indicating that radiographic processes were applicable to the duties performed more than any other process. Eddy current was considered as least applicable with 16.6 per cent. Question number 4 referred to nondestructive testing research support. The data showed 31.8 per cent of the respondents believed that ultrasonic testing needed support through research. Only 4.5 per cent of the respondents marked penetrant as needing research support.

TABLE VI

RESPONSE DATA PERTAINING TO IMPORTANCE OF PHASES OF NONDESTRUCTIVE TESTING

Questions Directed to Respondent	Number of Responses in Phases of NDT											
	All Methods		Penetrant		Magnetic		Eddy Current		Ultrasonic		Radiographic	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Question 1	169	85.3	24	12.1	26	13.1	13	6.5	29	14.6	20	10.1
Question 2	22	11.1	20	10.1	29	14.6	51	25.7	129	65.1	54	27.2
Question 3	22	11.1	71	35.8	70	35.3	33	16.6	54	27.2	87	43.9
Question 4	28	14.1	9	4.5	13	6.5	43	21.7	63	31.8	22	11.1

Recommended Research in Nondestructive Testing

Respondents were requested to indicate recommended areas of research in support of the proposed program in nondestructive testing. Appendix V shows twenty-three areas where further research was recommended. The listing has a broad range of coverage, running from dye experimentation to endurance life expectancies of graphite rocket motor nozzles. In fact, there are twenty-three separate areas where research was recommended. One of the most needed fields for research was indicated in the area of rocket motors. This has been brought about through the requirements of national defense and the space program.

Other Forms of Energy Needed in Support of Nondestructive Testing

Although nondestructive testing utilizes several forms of energy during its processes, many additional forms of energy were recommended for support to the proposed program. A review of Appendix W reflects twenty-four recommended sources of energy to be used in support of nondestructive testing. Even though some types of these forms of energy are currently being utilized in the testing processes, respondents believed that further use of these energy forms should be made. The laser was rejected by 8 per cent of these respondents in regard to the five main areas of nondestructive testing; however, it was recommended as another form of energy which should be used in support of testing.

Branches of Industry Needing Support of Nondestructive Testing

The inspections covered by nondestructive testing processes are vast and reach into many manufacturing areas. However, the need for higher degrees of quality control has introduced increased levels of standards. Industries providing public transportation are being pressed to assure higher safety standards. The aircraft industry, especially, is being forced to use all known methods of nondestructive testing in order to provide safer aircraft. Specifications and standards are constantly being upgraded to fulfill the requirements of increased safety. Pressure vessels are now being checked with all methods of testing due to higher standards being demanded.

Appendix X indicates the respondents' answers to the question: "In addition to your area of NDT, what other branch of industry do you feel should be supported with selected areas of NDT?" Twenty-two industries are listed, indicating that respondents are anxious to assure higher levels of safety in most of the metal manufacturing industries.

Technologies Recommended For Instruction in Nondestructive Testing

Table VII indicates seventeen distinct technologies where nondestructive testing processes are needed, based on recommendations of respondents.

TABLE VII

TECHNOLOGIES RECOMMENDED FOR INSTRUCTION IN NONDESTRUCTIVE TESTING

Technology	Response		No Comment	
	No.	%	No.	%
Metallurgy	170	85.8	28	14.2
Automotive	163	82.3	35	17.7
Welding	163	82.3	35	17.7
Aerospace	160	80.8	38	19.2
Bonding	160	80.8	38	19.2
Mechanical	158	79.7	40	20.3
Machine Shop	152	76.7	46	23.3
Refrigeration	152	76.7	46	23.3
Electrical	151	76.2	47	23.8
Plastics	151	76.2	47	23.8
Civil	150	75.7	48	24.3
Power Transmission	149	75.2	49	24.8
Production	149	75.2	49	24.8
Electro-mechanical	148	74.7	50	25.3
Sheet Metal	147	74.2	51	25.8
Plating	145	73.2	53	26.8
Electronic	138	69.6	60	30.4

Table VII indicates that the field of metallurgy was checked by more respondents than any other technological area, 85.8 per cent. Welding, bonding, aerospace, and automotive were also ranked at the top of the degree of response. These technologies are involved in public transportation systems. All seventeen technologies were checked by more than 70 per cent of the respondents, except electronic which was checked by 69.6 per cent. With respect to the "No Comment" column, no explanation was given.

Nondestructive Testing Employment and Training Data

Each business concern was requested to indicate its present and future employee needs in nondestructive testing and inspection. Table VIII reflects a consolidation of these needs.

TABLE VIII

NONDESTRUCTIVE TESTING EMPLOYMENT DATA

Population	Employees Now Employed in NDT	Employees Now Needed in NDT	Additional Employee Need in Five Years	Total Employees Needed in Five Years
198	1,875	2,065	656	2,721

The sampling population consisted of 198 respondents from those areas shown in Appendix I. From the 198 companies representing the samples, 1,875 personnel were employed in nondestructive testing processes. These respondents indicated a current need of 2,065 employees or an increase of 190. The five year projected need shows a current shortage of 846 technicians.

Question 11 in the Questionnaire asked: "Would you hire a technician who has completed the above training if space were available?" Table IX indicates the response to this question.

TABLE IX

RESPONSE TO QUESTION: "WOULD YOU HIRE A TECHNICIAN WHO HAS COMPLETED THE ABOVE TRAINING IF SPACE WERE AVAILABLE?"

Yes		No		No Comment	
No.	%	No.	%	No.	%
140	70.7	16	8	42	21.2

One hundred forty or 70.7 per cent of the respondents shown in Table IX indicated they would hire the graduate while 8 per cent indicated they would not. The reason for not hiring the graduate was explained by a few respondents. Several companies have hiring procedures which require that nondestructive testing personnel be transferred in from other departments of the company. This policy then eliminates the direct hiring of recent graduates for duty in the nondestructive testing department. This probably would not prevent their being employed in other positions with the understanding that they would later be moved into nondestructive testing provided their services were satisfactory.

Question 13 in the Questionnaire asked: "Would a graduate of this proposed NDT program reduce your on-the-job training time?" Table X shows the response to this question. According to Table X, 138 or 69.6 per cent of the responses indicated that the proposed training program in nondestructive testing would reduce their on-the-job training.

TABLE X

RESPONSE TO QUESTION: "WOULD A GRADUATE
OF THIS PROPOSED NDT PROGRAM
REDUCE YOUR OJT TIME?"

Yes		No		No Comment	
No.	%	No.	%	No.	%
138	69.6	11	5.5	49	24.7

As shown in Table X, eleven respondents pointed out that on-the-job training was part of the job and would therefore not reduce the training time. With respect to the "No Comment" column, no explanation was given.

A majority of the respondents indicated that on-the-job training was required of newly employed nondestructive personnel. Table XI points out the training programs common to this population. Programs ranged in length of time from thirty to 2500 hours, while eleven programs were indicated as being continuous. Twenty-six distinct on-the-job training programs were provided. The only distinction among the programs shown in the responses was the length of time. Most newly assigned personnel are placed in training programs according to their skills and needs; however, some newly hired

TABLE XI

ON-THE-JOB TRAINING HOURS ASSIGNED TO NEW PERSONNEL

Hours of On-The-Job Training											
40-80		81-200		201-360		361-720		721-2500		More or Continuous	
No.	Hrs.	No.	Hrs.	No.	Hrs.	No.	Hrs.	No.	Hrs.	No.	Hrs.
5	30	1	100	28	240	3	400	5	1500	11	
11	40	2	120	2	312	1	480	5	2000		
2	50	3	150	7	320	6	500	3	2500		
2	60	20	160	7	360	4	600				
1	70	1	168			21	700				
14	80	3	180								
		3	200								
Total 35	..	33	...	44	...	35	...	13	....	11	....

personnel are given specified training regardless of their skills. Table XI indicates that the most popular length of time for a training program was conducted for 240 hours.

Additional Program Development Recommendations

Most respondents did not attempt to answer the question: "Will you add any comments which will further the development of this proposed program?" However, several comments were received and are listed in Appendix Y. Most of these recommendations are general in nature and directly related to the subject matter pertaining to nondestructive testing.

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CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

Summary

This study was concerned with the need to survey Texas industry in order to provide technical data for junior college instructional programs in nondestructive testing and inspection. Data were obtained through the means of a questionnaire which was sent to selected manufacturers and service companies in Texas. A three-week period of time was used in collecting data. The returned questionnaires were examined for adequacy and subsequently processed for evaluation.

Nineteen separate areas of technical information were received from a cross section of Texas metal working and related industries. Each area of information was processed and integrated into the total findings of the study.

The main objectives of this study are pointed out in the following summaries. Chapter I was concerned with the purpose of the study, a statement of the problem, and the related hypotheses. In addition, the background of the problem was investigated in order to present its significance to today's industry. Chapter II was confined to the related literature in an effort to support the background of the problem and to provide a better understanding of the study. Chapter III provided implementing and operational instructions for accomplishing the survey and gathering the data. Chapter IV was involved in the analyses of data in order that recommendations could be made from the findings and conclusions. Chapter V presents the findings, conclusions, and recommendations resulting from this study.

Findings

Items of information that were processed from the survey were arranged into individual groups and studied so that findings were developed. Due to the comprehensiveness of the study, many findings were obtained and are listed below.

1. Hypothesis I was rejected by respondents relative to twenty-four items of subject matter.

2. Hypothesis II was rejected by the respondents in all main areas of subject matter.

3. Hypothesis III was rejected by respondents in nineteen items of subject matter.

4. The population's response to all items of subject matter points out that more than 40 per cent indicated that the subjects should be discussed in general, while one-third believed that detailed discussion was essential.

5. Respondents indicated that the majority of subject matter items should be discussed up to two hours duration.

6. General education subjects were recommended to be retained in the proposed program of nondestructive testing and inspection. Most respondents indicated that a general discussion of these subjects was sufficient.

7. Eighteen additional items of subject matter were recommended to be included in the proposed instructional program and are shown in Appendix U.

8. Most respondents indicated that the technician should be proficient in all main phases of the field of nondestructive testing.

9. The least important phase of testing was noted as eddy current.

10. Most respondents believed that ultrasonics was growing in demand faster than any other phase of testing, while penetrant was the least growing phase.

11. Radiographic processes were used by respondents more than any other, while eddy current was used the least.

12. Respondents pointed out that ultrasonics should be supported with research ahead of other phases of testing, while penetrant was shown as needing little research.

13. Research was recommended in twenty-three separate areas of knowledge so that nondestructive testing and inspection could be advanced in effectiveness.

14. Twenty-four modified sources of energy were recommended as being needed in carrying out more efficient testing and inspection procedures.

15. Twenty-two industries were shown as requiring inspection support from nondestructive testing. Metallurgy was indicated as the technology needing this support more than any other technical field or subject.

16. There is a current shortage of trained technicians in the field of nondestructive testing and inspection. This shortage is accelerating due to the small numbers of qualified personnel entering this field. Besides providing for the full staff of 1,875 specialists and technicians, there is an additional need of 846 technicians throughout Texas in the next five years in regard to the population studied. Many respondents indicated the overall shortage was critical.

17. Most respondents indicated they would hire a graduate of the proposed program if space were available.

18. Most respondents indicated that hiring technicians who were graduates of the proposed program would reduce the need for on-the-job training.

19. Twenty-six distinct on-the-job training programs were shown as being in progress throughout the population.

20. Ten additional recommendations were made which would further the development of the program.

Conclusions

From the above findings, the following conclusions result:

1. Subject matter listed in the survey instrument should be retained and integrated into a comprehensive

program of instruction in nondestructive testing, inspection, and evaluation.

2. The additional recommended items of subject matter should be included in the proposed program.

3. The amount of time required for teaching each of the indicated subjects should be closely associated with the emphasis placed on each subject, so that results of lecture and laboratory facilities will be effective.

4. The phases of nondestructive testing should be given priorities in importance and in needs in planning the proposed program.

5. Research in all phases of nondestructive testing is essential; however, immediate action is needed in ultrasonic research.

6. Research is needed in many other areas of knowledge in support of nondestructive testing and should be investigated to determine the exact requirements before commencing.

7. More use of other forms of energy is needed so that safer structural parts and safer vehicles will be provided.

8. More use of nondestructive testing and inspection processes is needed in related manufacturing fields and in engineering designs.

9. There is a current shortage of skilled nondestructive testing technicians.

10. Graduates of the proposed instructional program will find positions in nondestructive testing processes.

11. Industrial training programs will be reduced upon assignment of skilled personnel.

Recommendations

Implications resulting from conclusions of this study point directly to the immediate need for recommendations to implement programs of instruction in nondestructive testing and inspection throughout industrial areas of Texas. Based on conclusions stemming from this study, the following recommendations are made:

1. Educational institutions, especially the junior colleges, should investigate the needs for nondestructive testing technicians in their geographical areas. If the need exists in their localities, programs of instruction should be organized and implemented within the least practical time. Throughout the state of Texas, the findings show a shortage of these technicians; therefore, many colleges should plan to implement these programs.

2. Administrators and curriculum personnel, in planning programs of instruction in nondestructive testing, should provide for instruction in the following main areas: penetrant, magnetic particle, eddy current, ultrasonics, and radiographic.

3. Because instructional programs in nondestructive testing and inspection processes require large expenditures of money, action should be taken by the colleges to request the Texas Education Agency and the federal government for

grants to be used in organizing, implementing, and conducting these programs. These grants should include funds for the purchase of equipment and for payment of faculty salaries.

4. Additional studies should be accomplished in order to determine courses and course contents to be included in a curriculum or instructional program for nondestructive testing, inspection, and evaluation of engineering materials.

APPENDIX

Appendix Page

A. Sample Letter to Manufacturer of NDT Equipment 92

B. Key Elements of Subject Matter Arranged in Outline Form 93

C. Degree of Emphasis to Be Placed on Each Item of Subject Matter 94

D. Time to Be Spent on Each Subject 95

E. The Completed Rating Scale 96

F. Jury Members 97

G. Letter to Jury Members 98

H. Questionnaire 99

I. Categories of Business Enterprises 113

J. Geographical Distribution of Population 115

K. Letter of Inquiry 116

L. Participation Indication 117

M. Acceptance Letter to Respondent 118

N. Follow-Up Letter 119

O. Final Follow-Up Letter 120

P. Per Cent of Population Not Recommending NDT Subject Matter For Discussion 121

Q. Significance of Response Data from Manufacturers and Service Companies 128

R. Significance of Response Data from Supervisors and Operators 159

Appendix Page

S. Rejected Items of Subject Matter 190

T. Recommended Time to Be Spent in Teaching Subject Matter 192

U. Additional Subject Matter Recommended in the Training of NDT Technicians 203

V. Recommended Research in Nondestructive Testing 204

W. Other Forms of Energy Which May Be Utilized in Support of Nondestructive Testing 205

X. Other Branches of Industry That Should Be Supported With Nondestructive Testing Processes 206

Y. Additional Program Development Recommendations 207

APPENDIX A

SAMPLE LETTER TO MANUFACTURER OF NDT EQUIPMENT

Gentlemen:

I am a doctoral student at North Texas State University and am completing my dissertation which pertains to nondestructive testing processes used in industry; that is, penetrant, magnetic particle, eddy current, ultrasonic, and radiographic. Because this study will be confined to Texas, I am inquiring to see if you could furnish me with the names of any manufacturers or service companies (airline, etc.) who use your equipment or those who use any other type of nondestructive testing equipment in Texas.

This information will help me accomplish this study and in turn, my findings will be made available to the junior colleges for curriculum planning purposes. My questionnaire will seek an answer to operational subject matter without indicating the equipment trade name. Any leads you can furnish me will be greatly appreciated. Thank you.

Sincerely,

Vernon L. Stokes

APPENDIX B

KEY ELEMENTS OF SUBJECT MATTER ARRANGED IN OUTLINE FORM*

SUBJECT MATTER TO BE TAUGHT
A. PENETRANT METHOD . . . .
EQUIPMENT . . . .
Operator's ability to use
Spot check type
Dye facilities
Fluorescent capability
Wet and dry methods
Portable type
Stationary type
SURFACE PREPARATION . . . .
Degreasing processes
Scale removal
Paint and plating removal
PENETRANTS. . . . .
Purpose of penetrants
Preparation of penetrants

*This listing of subject matter is an extract of a larger outline which was developed into part of the questionnaire.

APPENDIX C

DEGREE OF EMPHASIS TO BE PLACED ON EACH ITEM OF SUBJECT MATTER*

FORMAT SENT TO JUDGES

DEGREE OF EMPHASIS to be placed on each item of subject matter				
Taught in detail	Emphasized	For general understanding	For familiarization	Some need to be taught
5	4	3	2	1
. .	. .	. .	. .	. .
. .	. .	. .	. .	. .

FINAL FORMAT

DEGREE OF EMPHASIS			
No need to be discussed	Discussed briefly	Discussed in general	Discussed in detail
1	2	3	4
. .	. .	. .	. .
. .	. .	. .	. .

*The rater will place a check mark in only one column to indicate the degree of emphasis he feels should be placed on each of the corresponding subjects.

APPENDIX D

TIME TO BE SPENT ON EACH SUBJECT*

FORMAT SENT TO JUDGES

	TIME
	Time in instructional hours or fraction
	. .
	. .

FINAL FORMAT

TIME			
Less than 1 hour	From 1 to 2 hours	From 2 to 3 hours	More than 3 hours
1	2	3	4
. . .	. .	. .	. .
. . .	. .	. .	. .

*In marking the Time Column sent to the judges, the rater would indicate in hours the number of hours he felt should be spent on the subject.

In marking the Final Format Time Column, the rater will place a check mark in only one column to indicate the number of hours he feels is necessary to be spent in teaching the subject.

APPENDIX E

THE COMPLETED RATING SCALE*

SUBJECT MATTER TO BE TAUGHT	DEGREE OF EMPHASIS				TIME			
	No need to be discussed	Discussed briefly	Discussed in general	Discussed in detail	Less than 1 hour	From 1 to 2 hours	From 2 to 3 hours	More than 3 hours
	1	2	3	4	1	2	3	4
A. PENETRANT METHOD								
EQUIPMENT								
1. Operator's ability to use								
2. Spot check type								
3. Dye facilities								
4. Fluorescent capability								
5. Wet and dry methods								
6. Portable type								

*The rater will place a check mark in one column under Degree of Emphasis and in one column under Time following each subject.

APPENDIX F

JURY MEMBERS

Mr. Don Norton
Magnaflux Corporation
6115 Denton Road
Dallas, Texas

Mr. Alvin E. Clark
McDonald-Douglas Company
424 Plainview Drive
Hurst, Texas

Mr. Dave D. Emerick
General Dynamics
North Grants Lane
Fort Worth, Texas

Mr. R. E. Wolters
General Dynamics
North Grants Lane
Fort Worth, Texas

Mr. Robert G. Dunn
Eastman Kodak Company
Dallas, Texas

Mr. Ralph E. Turner
Eastman Kodak Company
and
President-Elect
American Society for NDT
Rochester, New York

APPENDIX G

LETTER TO JURY MEMBERS

Dear Sir:

I am a doctoral student at North Texas State University and am currently in the process of writing my dissertation, " A Study of Nondestructive Testing and Inspection Processes Used in Industry with Implications for Program Planning in the Junior Colleges of Texas." This study will require the use of a comprehensive questionnaire which will be sent to NDT personnel with instructions for accomplishment and return to me. Answers shown in the questionnaire will be used in drawing conclusions for organizing a two-year junior college program in nondestructive testing, inspection, and evaluation.

The attached questionnaire has been prepared by me and is supposed to reflect a comprehensive coverage of the field of NDT. Some detail is essential in order to maintain identity of subject matter; therefore, this requires several pages of pertinent information. Each indicated subject is to be rated by an individual who is competent in the area of nondestructive testing. As you see, I am comparing a degree of emphasis between supervisors (or administrators) and operators and between manufacturers and service companies (airlines, ship yards, trucking, sales, etc.). The summation of these ratings will then provide implications for organizing a program.

As a judge in helping me accomplish this study, please review this questionnaire and either delete, add, or amend to the indicated subject matter in order that the resultant questionnaire will be meaningful and comprehensive. Agreement among four of you will constitute validity of subject matter. Please feel free to complete the questionnaire in a manner that you believe will provide the maximum of benefits from this study.

Sincerely,

Vernon L. Stokes

APPENDIX H

NONDESTRUCTIVE TESTING AND INSPECTION TECHNICIAN

Two-Year Junior College Program

QUESTIONNAIRE

I

DIRECTIONS: A manufacturer is one who uses nondestructive testing and inspection during the manufacture of the part. A service company is one which uses nondestructive testing and inspection while the part is in service or after it has been manufactured. Please complete the following:

1. You represent (check one):
   a. ( ) Manufacturing company
   b. ( ) Service company
   c. ( ) Other (specify)
   ____

2. You are (check one):
   a. ( ) Supervisor
   b. ( ) Operator
   c. ( ) Other (specify)
   ____

II

DIRECTIONS: On the following pages place a check mark in only one numbered column following each numbered subject according to the degree of emphasis you feel should be placed on this subject. Please indicate your response to all items in each lettered phase of the rating scale in accordance with your best judgement even though you may not be involved in these items. If an entire phase does not pertain to your job or if you are not capable of answering this phase of nondestructive testing, then leave the phase blank. However, if you feel capable of indicating your feelings in this particular phase, then mark all rows according to your best judgement. Lecture and laboratory facilities will be available.

On the same subject matter line and immediately following the degree of emphasis rating, place a check mark in the applicable TIME column. Your response will indicate the length of time you believe is necessary to devote to each of the numbered subjects. The degree of emphasis to be placed on each numbered subject plus the recommended time to be spent on each subject will be used in determining the scope of subject matter needed in organizing a curriculum for the nondestructive testing and inspection program.

SUBJECT MATTER TO BE TAUGHT	DEGREE OF EMPHASIS				TIME			
	No need to be discussed	Discussed briefly	Discussed in general	Discussed in detail	Less than 1 hour	From 1 to 2 hours	From 2 to 3 hours	More than 3 hours
	1	2	3	4	1	2	3	4
A. PENETRANT METHOD								
EQUIPMENT								
1. Operator's ability to use								
2. Spot check type								
3. Dye facilities								
4. Fluorescent capability								
5. Wet and dry methods								
6. Portable type								
7. Stationary type								
SURFACE PREPARATION								
8. Degreasing processes								
9. Scale removal								
10. Paint and plating removal								
PENETRANTS								
11. Purpose of penetrants								
12. Preparation of penetrants								
13. Water washable fluorescent								
14. Post-emulsification fluorescent								

	1	2	3	4	1	2	3	4
15. Water emulsification visible dye								
16. Application to surfaces								
17. Area temperature								
18. Time at penetration								
19. Emulsifiers								
20. Safety precautions								
WASHING								
21. Coarse spray								
22. Solid stream or dip								
23. Liquid temperature								
24. Black light check								
DEVELOPER								
25. Purpose of developers								
26. Wet procedure								
27. Drying time								
28. Dry procedure								
29. Persistence characteristics								
INSPECTION WITH BLACK LIGHT								
30. Procedures								
31. Illumination levels								
32. Black light filters								
33. Black light intensities								
34. Control blocks								
35. Surface crack recognition								
36. Porosity at surfaces								
37. Shut and seam recognition								
38. Machine marks								
39. Post cleaning processes								
EVALUATION TECHNIQUES								
40. Need for standards								
41. Appraisal of object inspected								

	1	2	3	4	1	2	3	4
B. MAGNETIC PARTICLE METHOD								
EQUIPMENT								
1. Operator's ability to use								
2. Portable type								
3. Stationary type								
4. Automatic type								
5. Liquids and powders								
6. Black light type								
7. Light sensitive instruments								
PRINCIPLES AND PURPOSES								
8. Theory of magnetism								
9. Purpose of magnetic fields								
10. Ferromagnetic materials								
11. Magnets and magnetism								
12. Dry method								
13. Wet method								
14. Filtered particle								
FLUX FIELDS								
15. Rules of fields								
16. Direct current								
17. Direct pulsating current								
18. Alternating current								
19. Bar-magnet principles								
20. Ring-magnet principles								
21. Continuous field								
22. Residual field								
23. Swinging field								
24. Length-diameter ratios								
25. Meters and strength of field								

	1	2	3	4	1	2	3	4
SURFACE DISCONTINUITIES								
26. Cleaning processes								
27. North-south pole factors								
28. Crack types								
29. Laps, seams, and pits								
30. Machine marks								
31. Geometric effects								
SUBSURFACE DEFECTS								
32. Surface indications								
33. Holes and porosity								
34. Metallic discontinuities								
35. Depth from surface relationships								
CIRCULAR METHOD								
36. Procedures								
37. Right-hand rule and flaws								
38. End-to-end current conduction								
39. Contact plates								
40. Contact prods and yokes								
41. Current calculations								
42. Overheating precautions								
43. Types of irregularities								
LONGITUDINAL METHOD								
44. Procedures								
45. External flow of current								
46. Use of coils and cables								
47. Current calculations								
48. Types of irregularities								
49. Demagnetization procedures								
EVALUATION TECHNIQUES								

	1	2	3	4	1	2	3	4
50. Use of standards								
51. Defect appraisal								
C. EDDY CURRENT METHOD								
EQUIPMENT								
1. Operator's ability to use								
2. Purpose of various types								
3. Automatic equipment								
4. Design characteristics								
5. Indicators and meters								
TEST-COIL ARRANGEMENTS								
6. Feed through								
7. Inside test								
8. Probe								
9. Forked								
IMPEDANCE-PLANE RESPONSE								
10. Feed back								
11. Reactance								
12. Magnitude								
13. Vector analyses								
14. Effects suppression								
15. Cathode ray								
16. Linear time base								
EDDY CURRENT PRINCIPLES								
17. Principles of eddy current								
18. Alternating current field								
19. Empty coil voltage								
20. Object influence in coil								
21. Primary coil characteristics								
22. Secondary coil characteristics								

	1	2	3	4	1	2	3	4
23. Coupling factors								
24. Signal-noise ratio								
25. Choice of coil								
26. Circular direction characteristics								
27. Surface to center factors								
28. Constants								
29. Amplitude and phase angle								
30. Depth penetration								
31. Temperature compensation								
IMPEDANCE								
32. Impedance changes								
33. Circuit arrangements								
34. Variation of object arrangement								
35. Properties of test object								
36. Coil-object characteristics								
PERMEABILITY								
37. Fundamentals								
38. Ferromagnetic objects								
39. Nonferromagnetic objects								
40. Selection of frequency								
FIELD STRENGTH								
41. Strength factors								
42. Distribution and penetration								
43. Internal and external coils								
TEST INDICATIONS								
44. Conductivity								
45. Comparator								
46. Hysteresis								

	1	2	3	4	1	2	3	4
TEST OBJECT SHAPE AND CIRCUITRY								
47. Geometry of shape								
48. Cylinder test								
49. Tube test								
50. Sphere test								
51. Sheet test								
IRREGULARITY RECOGNITION								
52. Flaw detection and identification								
53. Mechanical properties of object								
EVALUATION TECHNIQUES								
54. Use of standards								
55. Appraisal of object								
D. ULTRASONIC METHOD								
EQUIPMENT CATEGORIES								
1. Operator's ability to use								
2. Purposes of different equipment								
3. Amplitude of through-energy type								
4. Amplitude and transit-time type								
5. Transducer loading factors								
6. Design requirements								
EQUIPMENT FUNCTIONS								
7. Frequency modulation								
8. Continuous oscillator								
9. Time pulsed								
10. Modulated oscillator								
11. Resonance								
12. A-scan system								
13. B-scan system								

	1	2	3	4	1	2	3	4
14. C-scan system								
15. Manipulators								
16. Bridges								
TEST SYSTEMS								
17. Through transmission								
18. Reflected transmission								
19. Single search								
20. Double search								
21. Straight beam								
22. Angle beam								
23. Generators								
24. Transducers								
25. Couplants								
26. Indicators and meters								
WAVE PROPAGATION								
27. Characteristics and principles								
28. Frequencies and ranges								
29. Stress ranges								
30. Wavelengths								
31. Vibrations								
32. Velocity								
33. Impedance								
34. Attenuation								
35. Reflection								
36. Refraction								
37. Diffraction								
38. Dispersion								
39. Mode conversion								

	1	2	3	4	1	2	3	4
40. Special effects								
41. Undesirables								
METHODS								
42. Contact								
43. Immersion								
44. Modified								
45. Resonance								
CALIBRATION								
46. Need for calibration								
47. Standards								
48. Major parameters								
DEFECT DETECTION								
49. Sensitiveness to reflections								
50. Resolution processes								
51. Energy-noise discrimination								
52. Size of defect determination								
53. Location of defect factors								
54. Kind of defect determination								
EVALUATION								
55. Defect comparison procedures								
56. Object appraisal								
E. RADIOGRAPHIC METHOD								
EQUIPMENT								
1. Operator's ability to use								
2. Purpose of types								
3. Fixed installation								
4. Mobile type								
5. X-ray type								
6. Gamma ray type								

	1	2	3	4	1	2	3	4
7. Design requirements								
8. Safety precautions and practices								
RADIATION								
9. Principles								
10. Types of rays								
11. Electronic sources								
12. Isotopic sources								
13. Sensitivity								
14. Intensity distribution								
15. Detection devices								
16. Handling procedures								
17. Primary effects								
18. Secondary effects								
19. Shielding procedures								
20. Absorption characteristics								
21. Scatter effects								
22. Pair production								
23. Protection and safety codes								
24. Radiation dose control								
PROCEDURES								
25. Shadow picture and geometry								
26. Focal spot and window								
27. Electromagnetic waves								
28. Types of methods and techniques								
29. Voltage and amperage factors								
30. Lasers								
31. Exposure factors and contrast								
32. Screens and filters								
33. Film characteristics and types								

	1	2	3	4	1	2	3	4
34. Laws and rules								
35. Object material and density								
36. Image quality factors								
37. Penetrameters								
38. Film processing								
EVALUATION TECHNIQUES								
39. Criteria for evaluation								
40. Defect identification								
41. Appraisal of object								
F. GENERAL EDUCATION								
1. Oral communication					/	/	/	/
2. Technical writing					/	/	/	/
3. Fundamentals of physics					/	/	/	/
4. Industrial chemistry					/	/	/	/
5. Fundamentals of electronics					/	/	/	/
6. Applied electronics					/	/	/	/
7. Applied algebra					/	/	/	/
8. Applied geometry					/	/	/	/
9. Applied trigonometry					/	/	/	/
10. Quality control					/	/	/	/
11. Metrology					/	/	/	/
12. Basic statistics					/	/	/	/
13. Manufacturing processes					/	/	/	/
14. Basic metallurgy					/	/	/	/
15. Heat treatment of metals					/	/	/	/
16. Specifications and standards					/	/	/	/
17. Operator equipment maintenance					/	/	/	/
18. Safety precautions					/	/	/	/

G. ADDITIONAL SUBJECT MATTER

If you feel that additional subject matter is necessary in training this NDT technician, please indicate your additions on the reverse side of this page. This additional information must be considered in the final formulation of a suggested curriculum for NDT technicians.

DIRECTIONS: Please check the appropriate spaces in the table below:

	PHASES OF NDT					
	All methods	Penetrant	Magnetic	Eddy current	Ultrasonic	Radiographic
1. Do you believe the technician should be proficient in all phases of NDT or in one or more phases?						
2. Which NDT phases appear to be growing into more usage?						
3. Which NDT phases have more applications in your area?						
4. Which NDT phases do you believe should be supported with additional research? Will you describe this research on the reverse side of this page?						

5. What other form of energy could be utilized in support of NDT?

____

6. In addition to your area of NDT, what other branches of industry do you feel should be supported with selected areas of NDT?

____

7. Should a specific amount of NDT be taught to technicians in other fields? Underline the technology that you believe should be supported with selected areas of NDT.

Mechanical, machine shop, welder, sheet metal, plater, bonding, power transmission, electronic, metallurgical, aerospace, automotive, refrigeration, production, plastics, civil, electro-mechanical, electrical, other (specify) ______________________________.

DIRECTIONS: The following questions should be completed by only one person designated by your company:

8. How many NDT personnel do you now employ? ____________________

9. How many NDT personnel could you now use? ____________________

10. During the next five years how many additional NDT technicians will you need? ____________________

11. Would you hire a technician who has completed the above training if space were available? ____________________

12. How many hours of on-the-job training do you normally provide newly assigned personnel? ____________________

13. Would a graduate of this proposed NDT program reduce your on-the-job training time? ____________________

14. Will you add any comments which will further the development of this proposed program? Use reverse side of this page for your comments.

FOR ALL RESPONDENTS:

Please see that you have checked all subject matter and time spaces.

Please see that you have answered all questions.

Do you desire a copy of the final results of this survey?
If you do, place your name and address below.

____
(name)

____
(address)

THANK YOU VERY MUCH FOR HELPING ME ACCOMPLISH THIS SURVEY.

PLACE QUESTIONNAIRE IN ATTACHED ENVELOPE AND MAIL TODAY.

APPENDIX I

CATEGORIES OF BUSINESS ENTERPRISES

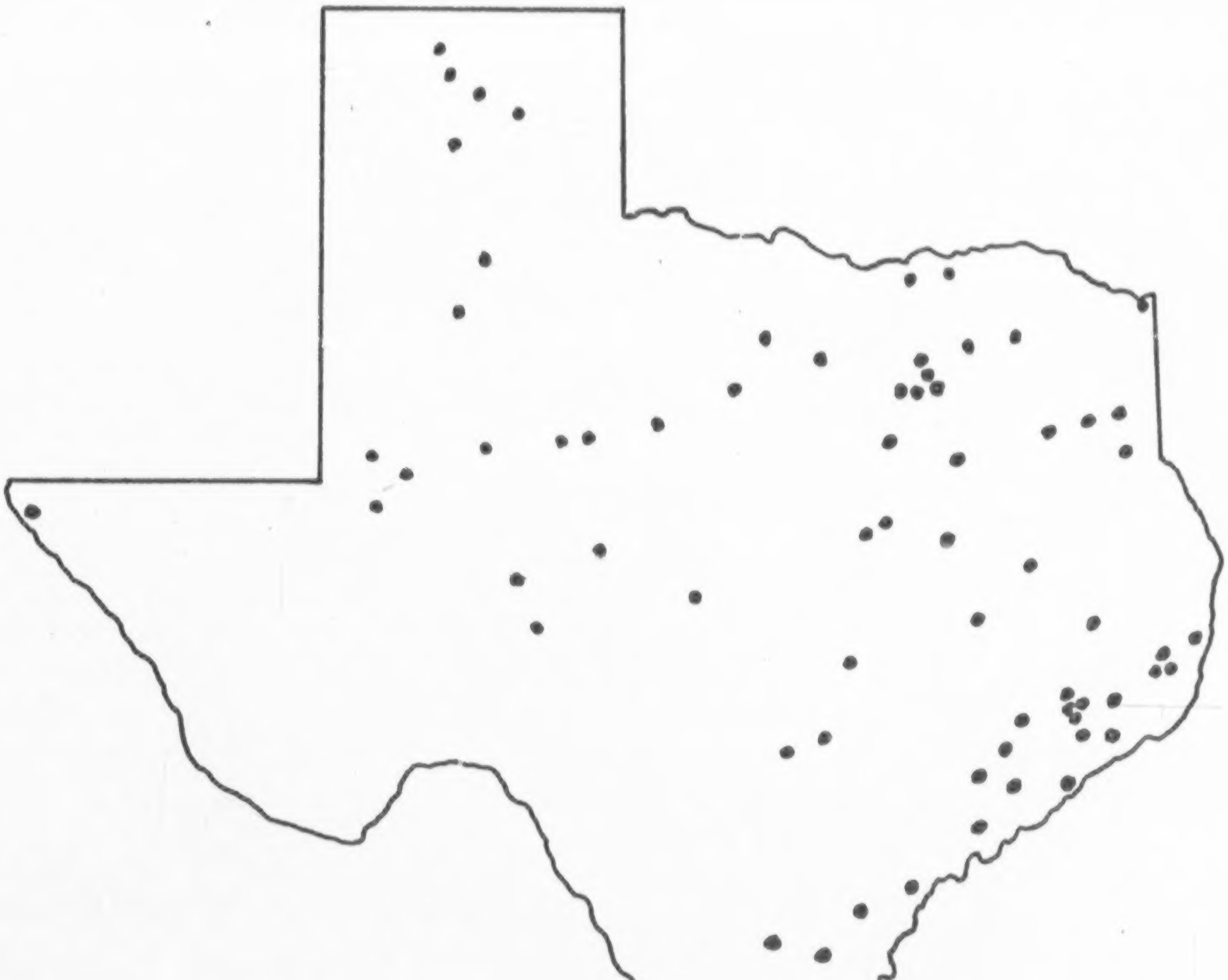
Air Conditioning Equipment
Aircraft Manufacturers (complete)
Aircraft Manufacturers (parts and sub-assemblies)
Aircraft Pilot Training
Air Force Bases
Airlines (freight)
Airlines (passenger)
Army
Arsenals
Aviation Agencies
Chemical Producers
Compressors
Communications
Drilling Companies
Electric Companies
Engine Manufacturers
Engineering Testing Laboratories
Gasoline and Oil Refiners
Gas Transmission Companies
Ground Support Equipment (aircraft)
Heat Treating Plants
Helicopter Maintenance
Helicopter Manufacturers
Iron and Steel Producers (mills)
Leasing Companies
Machinery Producers
Machine Shops
Manufacturers (general)
Mechanical Fabricators
Metal Containers
Metal Foundries
Metallurgical Companies
Metal Parts Manufacturers
Metal Shapes Fabricators
Mining Equipment Manufacturers
Missiles Manufacturers
Munitions Manufacturers
National Aeronautics and Space Administration
Naval Air Stations
Nondestructive Testing Equipment Manufacturers
Nonferrous Metal Producers
Ordnance Plants
Pipeline Installations

APPENDIX I --Continued

Plastic Manufacturers
Plating Plants
Railroads
Railroad Parts Manufacturers
Research Centers
Road Machinery Manufacturers
Scientific Equipment Manufacturers
Shipbuilders and Shipyards
Space Hardware
Tank Manufacturers
Tool Manufacturers
Turbine Manufacturers
Valves and Related Parts
Vehicle Manufacturers (passenger)
Vehicle Manufacturers (private)
Welding Fabricators

APPENDIX J

GEOGRAPHICAL DISTRIBUTION OF POPULATION



APPENDIX K

LETTER OF INQUIRY

I am a doctoral student at North Texas State University and am writing to request your help in a state wide survey pertaining to nondestructive testing. This study is being conducted in cooperation with the Division of Occupational Research and Development, Texas Education Agency. Recently, the National Materials Advisory Board completed research in nondestructive testing for the Department of Defense. A recommendation of this board is that educational institutions organize and provide educational programs in nondestructive testing as soon as possible.

My dissertation, "A Study of Nondestructive Testing and Inspection Processes Used in Industry With Implications For Program Planning in the Junior Colleges of Texas," will help implement the Department of Defense study by providing a formal program in nondestructive testing. If your company performs nondestructive testing, would you participate in this study? Participation will require the completion of a questionnaire by persons chosen by you who are currently working in NDT processes. Only from industrial and service personnel can I obtain the needed data that can be arranged into a college curriculum for the purpose of producing qualified NDT technicians. Your help is urgently needed.

If you will participate, please indicate the names of one NDT operator and one NDT supervisor on the enclosed form. I will then send these persons a copy of the questionnaire for accomplishment. Any other qualified personnel may participate. All answers will be considered confidential.

You will be notified of the final results of this study if you desire this information. Please complete the enclosed form and return to me, whatever your decision may be. Thank you.

Approved:

Dr. William A. Miller
Professor of Education
Project Officer

Sincerely,

Vernon L. Stokes
Investigator

APPENDIX L

PARTICIPATION INDICATION

PLEASE COMPLETE THE FOLLOWING INFORMATION, ENCLOSE IN ATTACHED ENVELOPE, AND MAIL TODAY.

Name and address of your company:

____

____

Kind of material manufactured or service rendered:

____

Check one of the following:

( ) We do not perform nondestructive testing.

( ) We do perform nondestructive testing.

Check one of the following:

( ) We will not participate in this study.

( ) We will participate in this study.

Names and addresses of persons who will participate:

Supervisor ________________________________
(name) (street) (city)

Operator ________________________________
(name) (street) (city)

Other ________________________________
(name) (street) (city)

Please circle the name of one person who will represent your company.

Persons whose names are shown above will be sent a copy of the questionnaire by return mail. Thank you for your help.

APPENDIX M

ACCEPTANCE LETTER TO RESPONDENT

Thank you for your participation in the Nondestructive Testing and Inspection Technician Study. Your completion of the attached questionnaire will help prepare a curriculum for a two-year junior college program in nondestructive testing and inspection. The answers you give will be considered confidential. Specific instructions for accomplishing the questionnaire precede each applicable section.

Upon completion of the questionnaire, place in attached envelope and mail today.

It is only through the application of your time and effort that a meaningful program can be initiated to help meet the needs of industry. Again, I thank you for your help.

Sincerely,

Vernon L. Stokes
Investigator

APPENDIX N

FOLLOW-UP LETTER

Approximately two weeks ago, I sent you a copy of a questionnaire pertaining to the Nondestructive Testing and Inspection Technician Study, but have not yet received your reply. Your response to this questionnaire is urgently desired because it is persons with your knowledge in this critical area who can help build this program. Will you respond today?

Should you need another copy of the questionnaire, please check the notation on this form and return to me. However, if you cannot now participate, check the notation below and return to me. Thank you for your consideration and help in this important study.

Sincerely,

Vernon L. Stokes

☐ Please send me another copy of the questionnaire.

☐ Please drop me from this study.

APPENDIX O

FINAL FOLLOW-UP LETTER

The questionnaire phase of the Nondestructive Testing and Inspection Technician study which I am accomplishing will be terminated on May 19, 1971. If you or your company still wish to participate by completing the questionnaire I sent to you, please forward it not later than May 19. After this date questionnaires cannot be used in one of the major parts of this study. If you have already forwarded your questionnaire, it will be recorded.

Participation among those Texas companies agreeing to participate has been very good, making the survey a success in attaining its objectives. Within the next few days, I hope you can find the time to complete the questionnaire and return to me; however, if you cannot, I still want to thank you.

Sincerely,

Vernon L. Stokes
Investigator

APPENDIX P

PER CENT OF POPULATION NOT RECOMMENDING NDT

SUBJECT MATTER FOR DISCUSSION

Per Cent of Response				
Subject Matter			No.	Per Cent
A	1	Operator's ability to use	3	1.5
A	2	Spot check type	1	.5
A	3	Dye facilities	1	.5
A	4	Fluorescent capability	1	.5
A	5	Wet and dry methods	-	-
A	6	Portable type	2	1.0
A	7	Stationary type	-	-
A	8	Degreasing processes	1	.5
A	9	Scale removal	1	.5
A	10	Paint and plating removal	-	-
A	11	Purpose of penetrants	4	2.0
A	12	Preparation of penetrants	5	2.5
A	13	Water washable fluorescent	1	.5
A	14	Post-emulsification fluorescent	1	.5
A	15	Water emulsification visible dye	2	1.0
A	16	Application to surfaces	-	-
A	17	Area temperature	3	1.5
A	18	Time at penetration	-	-
A	19	Emulsifiers	2	1.0
A	20	Safety precautions	2	1.0
A	21	Coarse spray	7	3.5
A	22	Solid stream or dip	5	2.5
A	23	Liquid temperature	3	1.5
A	24	Black light check	2	1.0
A	25	Purpose of developers	4	2.0
A	26	Wet procedure	3	1.5
A	27	Drying time	2	1.0
A	28	Dry procedure	3	1.5
A	29	Persistence characteristics	2	1.0
A	30	Procedures	7	3.5
A	31	Illumination levels	1	.5
A	32	Black light filters	1	.5
A	33	Black light intensities	1	.5

APPENDIX P --Continued

Per Cent of Response

Subject Matter			No.	Per Cent
A	34	Control blocks	4	2.0
A	35	Surface crack recognition	3	1.5
A	36	Porosity at surfaces	1	.5
A	37	Shut and seam recognition	2	1.0
A	38	Machine marks	4	2.0
A	39	Post cleaning processes	3	1.5
A	40	Need for standards	7	3.5
A	41	Appraisal of object inspected	5	2.5
B	1	Operator's ability to use	4	2.0
B	2	Portable type	2	1.0
B	3	Stationary type	2	1.0
B	4	Automatic type	1	.5
B	5	Liquids and powders	-	-
B	6	Black light type	1	.5
B	7	Light sensitive instruments	1	.5
B	8	Theory of magnetism	1	.5
B	9	Purpose of magnetic fields	-	-
B	10	Ferromagnetic materials	-	-
B	11	Magnets and magnetism	1	.5
B	12	Dry method	1	.5
B	13	Wet method	1	.5
B	14	Filtered particle	10	5.0
B	15	Rules of fields	3	1.5
B	16	Direct current	3	1.5
B	17	Direct pulsating current	5	2.5
B	18	Alternating current	4	2.0
B	19	Bar-magnet principles	2	1.0
B	20	Ring-magnet principles	2	1.0
B	21	Continuous field	5	2.5
B	22	Residual field	6	3.0
B	23	Swinging field	11	5.5
B	24	Length-diameter ratios	6	3.0
B	25	Meters and strength of field	-	-
B	26	Cleaning processes	3	1.5
B	27	North-south pole factors	-	-
B	28	Crack types	-	-
B	29	Laps, seams, and pits	2	1.0
B	30	Machine marks	1	.5
B	31	Geometric effects	1	.5
B	32	Surface indications	1	.5

APPENDIX P --*Continued*

Per Cent of Response		
Subject Matter	No.	Per Cent
B 33 Holes and porosity	-	-
B 34 Metallic discontinuities	-	-
B 35 Depth from surface relationships	3	1.5
B 36 Procedures	7	3.5
B 37 Right-hand rule and flaws	4	2.0
B 38 End-to-end current conduction	2	1.0
B 39 Contact plates	2	1.0
B 40 Contact prods and yokes	3	1.5
B 41 Current calculations	3	1.5
B 42 Overheating precautions	2	1.0
B 43 Types of irregularities	1	.5
B 44 Procedures	7	3.5
B 45 External flow of current	1	.5
B 46 Use of coils and cables	1	.5
B 47 Current calculations	1	.5
B 48 Types of irregularities	2	1.0
B 49 Demagnetization procedures	3	1.5
B 50 Use of standards	2	1.0
B 51 Defect appraisal	5	2.5
C 1 Operator's ability to use	3	1.5
C 2 Purpose of various types	1	.5
C 3 Automatic equipment	2	1.0
C 4 Design characteristics	2	1.0
C 5 Indicators and meters	1	.5
C 6 Feed through	2	1.0
C 7 Inside test	2	1.0
C 8 Probe	2	1.0
C 9 Forked	3	1.5
C 10 Feed back	5	2.5
C 11 Reactance	6	3.0
C 12 Magnitude	6	3.0
C 13 Vector analyses	11	5.5
C 14 Effects suppression	6	3.0
C 15 Cathode ray	7	3.5
C 16 Linear time base	6	3.0
C 17 Principles of eddy current	5	2.5
C 18 Alternating current field	2	1.0
C 19 Empty coil voltage	2	1.0
C 20 Object influence in coil	2	1.0

APPENDIX P --Continued

Per Cent of Response

Subject Matter			No.	Per Cent
C	21	Primary coil characteristics	2	1.0
C	22	Secondary coil characteristics	2	1.0
C	23	Coupling factors	1	.5
C	24	Signal-noise ratio	3	1.5
C	25	Choice of coil	3	1.5
C	26	Circular direction characteristics	2	1.0
C	27	Surface to center factors	3	1.5
C	28	Constants	2	1.0
C	29	Amplitude and phase angle	1	.5
C	30	Depth penetration	2	1.0
C	31	Temperature compensation	5	2.5
C	32	Impedance changes	4	2.0
C	33	Circuit arrangements	5	2.5
C	34	Variation of object arrangement	3	1.5
C	35	Properties of test object	4	2.0
C	36	Coil-object characteristics	5	2.5
C	37	Fundamentals	2	1.0
C	38	Ferromagnetic objects	2	1.0
C	39	Nonferromagnetic objects	2	1.0
C	40	Selection of frequency	2	1.0
C	41	Strength factors	3	1.5
C	42	Distribution and penetration	1	.5
C	43	Internal and external coils	3	1.5
C	44	Conductivity	1	.5
C	45	Comparator	2	1.0
C	46	Hysteresis	4	2.0
C	47	Geometry of shape	6	3.0
C	48	Cylinder test	4	2.0
C	49	Tube test	3	1.5
C	50	Sphere test	3	1.5
C	51	Sheet test	5	2.5
C	52	Flaw detection and identification	1	.5
C	53	Mechanical properties of object	1	.5
C	54	Use of standards	1	.5
C	55	Appraisal of object	2	1.0
D	1	Operator's ability to use	3	1.5
D	2	Purposes of different equipment	-	-
D	3	Amplitude of through-energy type	1	.5
D	4	Amplitude and transit-time type	1	.5
D	5	Transducer loading factors	1	.5
D	6	Design requirements	2	1.0

APPENDIX P --Continued

Per Cent of Response

Subject Matter		No.	Per Cent
D 7	Frequency modulation	2	1.0
D 8	Continuous oscillator	2	1.0
D 9	Time pulsed	2	1.0
D 10	Modulated oscillator	3	1.5
D 11	Resonance	2	1.0
D 12	A-scan system	2	1.0
D 13	B-scan system	2	1.0
D 14	C-scan system	5	2.5
D 15	Manipulators	3	1.5
D 16	Bridges	3	1.5
D 17	Through transmission	2	1.0
D 18	Reflected transmission	2	1.0
D 19	Single search	-	-
D 20	Double search	-	-
D 21	Straight beam	1	.5
D 22	Angle beam	3	1.5
D 23	Generators	2	1.0
D 24	Transducers	1	.5
D 25	Couplants	1	.5
D 26	Indicators and meters	2	1.0
D 27	Characteristics and principles	-	-
D 28	Frequencies and ranges	-	-
D 29	Stress ranges	1	.5
D 30	Wavelengths	1	.5
D 31	Vibrations	2	1.0
D 32	Velocity	-	-
D 33	Impedance	-	-
D 34	Attenuation	-	-
D 35	Reflection	1	.5
D 36	Refraction	1	.5
D 37	Diffraction	1	.5
D 38	Dispersion	-	-
D 39	Mode conversion	1	.5
D 40	Special effects	3	1.5
D 41	Undesirables	3	1.5
D 42	Contact	1	.5
D 43	Immersion	1	.5
D 44	Modified	1	.5
D 45	Resonance	1	.5
D 46	Need for calibration	2	1.0

APPENDIX P --Continued

Per Cent of Response		
Subject Matter	No.	Per Cent
D 47 Standards	1	.5
D 48 Major parameters	3	1.5
D 49 Sensitiveness to reflections	3	1.5
D 50 Resolution processes	2	1.0
D 51 Energy-noise discrimination	1	.5
D 52 Size of defect determination	4	2.0
D 53 Location of defect factors	3	1.5
D 54 Kind of defect determination	1	.5
D 55 Defect comparison procedures	5	2.5
D 56 Object appraisal	5	2.5
E 1 Operator's ability to use	2	1.0
E 2 Purpose of types	1	.5
E 3 Fixed installation	-	-
E 4 Mobile type	1	.5
E 5 X-ray type	2	1.0
E 6 Gamma ray type	6	3.0
E 7 Design requirements	3	1.5
E 8 Safety precautions and practices	5	2.5
E 9 Principles	5	2.5
E 10 Types of rays	1	.5
E 11 Electronic sources	2	1.0
E 12 Isotopic sources	2	1.0
E 13 Sensitivity	1	.5
E 14 Intensity distribution	2	1.0
E 15 Detection devices	1	.5
E 16 Handling procedures	2	1.0
E 17 Primary effects	1	.5
E 18 Secondary effects	2	1.0
E 19 Shielding procedures	1	.5
E 20 Absorption characteristics	1	.5
E 21 Scatter effects	1	.5
E 22 Pair production	4	2.0
E 23 Protection and safety codes	4	2.0
E 24 Radiation dose control	4	2.0
E 25 Shadow picture and geometry	4	2.0
E 26 Focal spot and window	3	1.5
E 27 Electromagnetic waves	1	.5
E 28 Types of methods and techniques	3	1.5
E 29 Voltage and amperage factors	3	1.5

APPENDIX P --Continued

Per Cent of Response

Subject Matter			No.	Per Cent
E	30	Lasers	16	8.0
E	31	Exposure factors and contrast	1	.5
E	32	Screens and filters	2	1.0
E	33	Film characteristics and types	3	1.5
E	34	Laws and rules	1	.5
E	35	Object material and density	1	.5
E	36	Image quality factors	1	.5
E	37	Penetrameters	6	3.0
E	38	Film processing	5	2.5
E	39	Criteria for evaluation	4	2.0
E	40	Defect identification	4	2.0
E	41	Appraisal of object	4	2.0
F	1	Oral communication	3	1.5
F	2	Technical writing	2	1.0
F	3	Fundamentals of physics	4	2.0
F	4	Industrial chemistry	4	2.0
F	5	Fundamentals of electronics	2	1.0
F	6	Applied electronics	6	3.0
F	7	Applied algebra	4	2.0
F	8	Applied geometry	2	1.0
F	9	Applied trigonometry	5	2.5
F	10	Quality control	-	-
F	11	Metrology	9	4.5
F	12	Basic statistics	8	4.0
F	13	Manufacturing processes	3	1.5
F	14	Basic metallurgy	2	1.0
F	15	Heat treatment of metals	2	1.0
F	16	Specifications and standards	1	.5
F	17	Operator equipment maintenance	3	1.5
F	18	Safety precautions	3	1.5

APPENDIX Q

SIGNIFICANCE OF RESPONSE DATA FROM MANUFACTURERS AND SERVICE COMPANIES

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
A 1	63		16	25.3	24	38.0	23	36.5		x
A 1		65	14	21.5	11	16.9	40	61.5		
A 2	63		25	39.6	24	38.0	14	22.2	x	
A 2		65	23	35.3	33	50.7	9	13.8		
A 3	63		26	41.2	26	41.2	11	17.4	x	
A 3		65	23	35.3	29	44.6	13	20.0		
A 4	63		17	26.9	27	42.8	19	30.1	x	
A 4		65	16	24.6	27	41.5	22	33.8		

*Manufacturer or Service Company.

**Includes data from Column 1.

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
A 5	63		16	25.3	29	46.0	18	28.5	x	
A 5		65	23	35.3	25	38.4	17	26.1		
A 6	63		25	39.6	26	41.2	12	19.0	x	
A 6		65	29	44.6	26	40.0	10	15.3		
A 7	63		21	33.3	24	38.0	18	28.5	x	
A 7		65	20	30.7	30	46.1	15	23.0		
A 8	63		24	38.0	24	38.0	15	23.8	x	
A 8		65	26	40.0	26	40.0	13	20.0		
A 9	63		28	44.4	21	33.3	14	22.2	x	
A 9		65	27	41.5	28	43.0	10	15.3		
A 10	63		26	41.2	22	34.9	15	23.8	x	
A 10		65	23	35.3	31	47.6	11	16.9		
A 11	63		10	15.8	33	52.3	20	31.7	x	
A 11		65	14	21.5	29	44.6	22	33.8		
A 12	63		19	30.1	29	46.0	15	23.8	x	
A 12		65	25	38.4	30	46.1	10	15.3		

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
A 13	63		18	28.5	25	39.6	20	31.7	x	
A 13		65	25	38.4	26	40.0	14	21.5		
A 14	63		17	26.9	25	39.6	21	33.3	x	
A 14		65	28	43.0	25	38.4	12	18.4		
A 15	63		30	47.6	22	34.9	11	17.4	x	
A 15		65	33	50.7	24	36.9	8	12.3		
A 16	63		21	33.3	23	36.5	19	30.1	x	
A 16		65	33	50.7	21	32.3	11	16.9		
A 17	63		35	55.5	19	30.1	9	14.2	x	
A 17		65	34	52.3	23	35.3	8	12.3		
A 18	63		25	39.6	21	33.3	17	26.9	x	
A 18		65	27	41.5	29	44.6	9	13.8		
A 19	63		27	42.8	21	33.3	15	23.8	x	
A 19		65	30	46.1	27	41.5	8	12.3		
A 20	63		25	39.6	22	34.9	16	25.3	x	
A 20		65	18	27.6	27	41.5	20	30.7		

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
A 21	63		35	55.5	16	25.3	12	19.0	x	
A 21		65	37	56.9	20	30.7	8	12.3		
A 22	63		36	57.1	16	25.3	11	17.4	x	
A 22		65	41	63.0	16	24.6	8	12.3		
A 23	63		36	57.1	17	26.9	10	15.8	x	
A 23		65	39	60.0	18	27.6	8	12.3		
A 24	63		26	41.2	23	36.5	14	22.2	x	
A 24		65	22	33.8	30	46.1	13	20.0		
A 25	63		21	33.3	24	38.0	18	28.5	x	
A 25		65	20	30.7	30	46.1	15	23.0		
A 26	63		26	41.2	17	26.9	20	31.7		x
A 26		65	27	41.5	28	43.0	10	15.3		
A 27	63		28	44.4	15	23.8	20	31.7		x
A 27		65	29	44.6	28	43.0	8	12.3		
A 28	63		26	41.2	15	23.8	22	34.9		x
A 28		65	30	46.1	25	38.4	10	15.3		

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
A 29	63		21	33.3	23	36.5	19	30.1	x	
A 29		65	27	41.5	24	36.9	14	21.5		
A 30	63		11	17.4	29	46.0	23	36.5	x	
A 30		65	13	20.0	22	33.8	30	46.1		
A 31	63		21	33.3	28	44.4	14	22.2	x	
A 31		65	23	35.3	27	41.5	15	23.0		
A 32	63		26	41.2	23	36.5	14	22.2	x	
A 32		65	27	41.5	26	40.0	12	18.4		
A 33	63		28	44.4	25	39.6	10	15.8	x	
A 33		65	28	43.0	23	35.3	14	21.5		
A 34	63		27	42.8	23	36.5	13	20.6	x	
A 34		65	29	44.6	24	36.9	12	18.4		
A 35	63		11	17.4	22	34.9	30	47.6	x	
A 35		65	13	20.0	25	38.4	27	41.5		
A 36	63		10	15.8	26	41.2	27	42.8	x	
A 36		65	14	21.5	32	49.2	19	29.2		

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
A 37	63		9	14.2	24	38.0	30	47.6	x	
A 37		65	13	20.0	30	46.1	22	33.8		
A 38	63		15	23.8	19	30.1	29	46.0	x	
A 38		65	24	36.9	23	35.3	18	27.6		
A 39	63		25	39.6	23	36.5	15	23.8	x	
A 39		65	31	47.6	23	35.3	11	16.9		
A 40	63		9	14.2	25	39.6	29	46.0	x	
A 40		65	14	21.5	19	29.2	32	49.2		
A 41	63		11	17.4	23	36.5	29	46.0	x	
A 41		65	14	21.5	15	23.0	36	55.3		
B 1	63		12	19.0	29	46.0	22	34.9	x	
B 1		65	12	18.4	18	27.6	35	53.8		
B 2	63		18	28.5	32	50.7	13	20.6	x	
B 2		65	21	32.3	29	44.6	15	23.0		
B 3	63		17	26.9	29	46.0	17	26.9	x	
B 3		65	21	32.3	28	43.0	16	24.6		

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
B 4	63		21	33.3	28	44.4	14	22.2	x	
B 4		65	23	35.3	26	40.0	16	24.6		
B 5	63		17	26.9	29	46.0	17	26.9	x	
B 5		65	22	33.8	28	43.0	15	23.0		
B 6	63		20	31.7	27	42.8	16	25.3	x	
B 6		65	19	29.2	29	44.6	17	26.1		
B 7	63		21	33.3	29	46.0	13	20.6	x	
B 7		65	20	30.7	28	43.0	17	26.1		
B 8	63		10	15.8	16	25.3	37	58.7	x	
B 8		65	12	18.4	26	40.0	27	41.5		
B 9	63		9	14.2	17	26.9	37	58.7	x	
B 9		65	12	18.4	25	38.4	28	43.0		
B 10	63		13	20.6	29	46.0	21	33.3	x	
B 10		65	17	26.1	26	40.0	22	33.8		
B 11	63		12	19.0	28	44.4	23	36.5	x	
B 11		65	17	26.1	25	38.4	23	35.3		

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
B 12	63		20	31.7	21	33.3	22	34.9	x	
B 12		65	22	33.8	27	41.5	16	24.6		
B 13	63		20	31.7	19	30.1	24	38.0	x	
B 13		65	24	36.9	26	40.0	15	23.0		
B 14	63		28	44.4	22	34.9	13	20.6	x	
B 14		65	25	38.4	32	49.2	8	12.3		
B 15	63		10	15.8	24	38.0	29	46.0	x	
B 15		65	13	20.0	27	41.5	25	38.4		
B 16	63		10	15.8	30	47.6	23	36.5	x	
B 16		65	13	20.0	28	43.0	24	36.9		
B 17	63		11	17.4	29	46.0	23	36.5	x	
B 17		65	14	21.5	28	43.0	23	35.3		
B 18	63		11	17.4	29	46.0	23	36.5	x	
B 18		65	15	27.2	21	38.1	19	34.5		
B 19	63		14	22.2	28	44.4	21	33.3	x	
B 19		65	20	30.7	26	40.0	19	29.2		

APPENDIX Q -- Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
B 20	63		14	22.2	29	46.0	20	31.7	x	
B 20		65	19	29.2	30	46.1	16	24.6		
B 21	63		16	25.3	27	42.8	20	31.7	x	
B 21		65	23	35.3	20	30.7	22	33.8		
B 22	63		16	25.3	24	38.0	23	36.5	x	
B 22		65	25	38.4	24	36.9	16	24.6		
B 23	63		18	28.5	25	39.6	20	31.7	x	
B 23		65	28	43.0	22	33.8	15	23.0		
B 24	63		17	26.9	23	36.5	23	36.5	x	
B 24		65	22	33.8	25	38.4	18	27.6		
B 25	63		11	17.4	29	46.0	23	36.5	x	
B 25		65	17	26.1	22	33.8	26	40.0		
B 26	63		21	33.3	30	47.6	12	19.0	x	
B 26		65	26	40.0	25	38.4	14	21.5		
B 27	63		19	30.1	23	36.5	21	33.3	x	
B 27		65	28	43.0	26	40.0	11	16.9		

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Mfg.	S.C.	No.	%	No.	%	No.	%	Retain	Reject
B 28	63		10	15.8	22	34.9	31	49.2	x	
B 28		65	21	32.3	22	33.8	22	33.8		
B 29	63		10	15.8	26	41.2	27	42.8	x	
B 29		65	17	26.1	26	40.0	22	33.8		
B 30	63		16	25.3	23	36.5	24	38.0	x	
B 30		65	17	26.1	30	46.1	18	27.6		
B 31	63		10	15.8	21	33.3	32	50.7	x	
B 31		65	13	20.0	27	41.5	25	38.4		
B 32	63		9	14.2	20	31.7	34	53.9	x	
B 32		65	13	20.0	23	35.3	29	44.6		
B 33	63		9	14.2	22	34.9	32	50.7	x	
B 33		65	11	16.9	29	44.6	25	38.4		
B 34	63		9	14.2	24	38.0	30	47.6	x	
B 34		65	10	15.3	31	47.6	24	36.9		
B 35	63		9	14.2	18	28.5	36	57.1	x	
B 35		65	15	23.0	24	36.9	26	40.0		

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
B 36	63		10	15.8	28	44.4	25	39.6	x	
B 36		65	16	24.6	19	29.2	30	46.1		
B 37	63		15	23.8	29	46.0	19	30.1	x	
B 37		65	14	21.5	37	56.9	14	21.5		
B 38	63		14	22.2	27	42.8	22	34.9	x	
B 38		65	17	26.1	35	53.8	13	20.0		
B 39	63		17	26.9	27	42.8	19	30.1	x	
B 39		65	18	27.6	36	55.3	11	16.9		
B 40	63		19	30.1	27	42.8	17	26.9	x	
B 40		65	20	30.7	36	55.3	9	13.8		
B 41	63		12	19.0	29	46.0	22	34.9	x	
B 41		65	18	27.6	29	44.6	18	27.6		
B 42	63		21	33.3	25	39.6	17	26.9	x	
B 42		65	23	35.3	26	40.0	16	24.6		
B 43	63		14	22.2	26	41.2	23	36.5	x	
B 43		65	18	27.6	24	36.9	23	35.3		

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
B 44	63		13	20.6	24	38.0	26	41.2	x	
B 44		65	12	18.4	23	35.3	30	46.1		
B 45	63		17	26.9	25	39.6	21	33.3	x	
B 45		65	18	27.6	35	53.8	12	18.4		
B 46	63		14	22.2	24	38.0	25	39.6	x	
B 46		65	19	29.2	29	44.6	17	26.1		
B 47	63		12	19.0	27	42.8	24	38.0	x	
B 47		65	15	23.0	34	52.3	16	24.6		
B 48	63		15	23.8	22	34.9	26	41.2	x	
B 48		65	16	24.6	26	40.0	23	35.3		
B 49	63		17	26.9	20	31.7	26	41.2	x	
B 49		65	18	27.6	26	40.0	21	32.3		
B 50	63		11	17.4	25	39.6	27	42.8	x	
B 50		65	12	18.4	17	26.1	36	55.3		
B 51	63		8	12.6	23	36.5	32	50.7	x	
B 51		65	10	15.3	15	23.0	40	61.5		

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly*		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
C 1	63		11	17.4	27	42.8	25	39.6		x
C 1		65	11	16.9	13	20.0	41	63.0		
C 2	63		17	26.9	24	38.0	22	34.9	x	
C 2		65	11	16.9	37	56.9	17	26.1		
C 3	63		20	31.7	25	39.6	18	28.5	x	
C 3		65	22	33.8	31	47.6	12	18.4		
C 4	63		21	33.3	28	44.4	14	22.2	x	
C 4		65	21	32.3	30	46.1	14	21.5		
C 5	63		21	33.3	26	41.2	16	25.3	x	
C 5		65	21	32.3	23	35.3	21	32.3		
C 6	63		16	25.3	30	47.6	17	26.9	x	
C 6		65	24	36.9	29	44.6	12	18.4		
C 7	63		15	23.8	30	47.6	18	28.5	x	
C 7		65	24	36.9	32	49.2	9	13.8		
C 8	63		17	26.9	31	49.2	15	23.8	x	
C 8		65	19	29.2	37	56.9	9	13.8		

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
C 9	63		17	26.9	31	49.2	15	23.8	x	
C 9		65	20	30.7	37	56.9	8	12.3		
C 10	63		20	31.7	26	41.2	17	26.9	x	
C 10		65	20	30.7	34	52.3	11	16.9		
C 11	63		18	28.5	28	44.4	17	26.9	x	
C 11		65	20	30.7	35	53.8	10	15.3		
C 12	63		20	31.7	28	44.4	15	23.8	x	
C 12		65	22	33.8	32	49.2	11	16.9		
C 13	63		19	30.1	22	34.9	22	34.9	x	
C 13		65	23	35.3	31	47.6	11	16.9		
C 14	63		23	36.5	22	34.9	18	28.5	x	
C 14		65	23	35.3	31	47.6	11	16.9		
C 15	63		24	38.0	23	36.5	16	25.3	x	
C 15		65	21	32.3	32	49.2	12	18.4		
C 16	63		24	38.0	24	38.0	15	23.8	x	
C 16		65	23	35.3	30	46.1	12	18.4		

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
C 17	63		13	20.6	19	30.1	31	49.2	x	
C 17		65	12	18.4	19	29.2	34	52.3		
C 18	63		12	19.0	27	42.8	24	38.0	x	
C 18		65	13	20.0	29	44.6	23	35.3		
C 19	63		17	26.9	25	39.6	21	33.3	x	
C 19		65	18	27.6	36	55.3	11	16.9		
C 20	63		15	23.8	28	44.4	20	31.7	x	
C 20		65	15	23.0	33	50.7	17	26.1		
C 21	63		15	23.8	22	34.9	26	41.2		x
C 21		65	13	20.0	38	58.4	14	21.5		
C 22	63		16	25.3	22	34.9	25	39.6	x	
C 22		65	13	20.0	30	46.1	22	33.8		
C 23	63		17	26.9	22	34.9	24	38.0		x
C 23		65	19	29.2	35	53.8	11	16.9		
C 24	63		18	28.5	24	38.0	21	33.3	x	
C 24		65	24	36.9	29	44.6	12	18.4		

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
C 25	63		13	20.6	27	42.8	23	36.5	x	
C 25		65	22	33.8	27	41.5	16	24.6		
C 26	63		17	26.9	28	44.4	18	28.5	x	
C 26		65	23	35.3	27	41.5	15	23.0		
C 27	63		19	30.1	29	46.0	15	23.8	x	
C 27		65	26	40.0	30	46.1	9	13.8		
C 28	63		22	34.9	25	39.6	16	25.3	x	
C 28		65	31	47.6	23	35.3	11	16.9		
C 29	63		15	23.8	29	46.0	19	30.1	x	
C 29		65	25	38.4	29	44.6	11	16.9		
C 30	63		14	22.2	24	38.0	25	39.6	x	
C 30		65	18	27.6	33	50.7	14	21.5		
C 31	63		23	36.5	25	39.6	15	23.8	x	
C 31		65	23	35.3	34	52.3	8	12.3		
C 32	63		17	26.9	29	46.0	17	26.9	x	
C 32		65	20	30.7	35	53.8	10	15.3		

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
C 33	63		23	36.5	26	41.2	14	22.2	x	
C 33		65	20	30.7	37	56.9	8	12.3		
C 34	63		20	31.7	28	44.4	15	23.8	x	
C 34		65	22	33.8	25	38.4	18	27.6		
C 35	63		19	30.1	22	34.9	22	34.9	x	
C 35		65	16	24.6	31	47.6	18	27.6		
C 36	63		20	31.7	22	34.9	21	33.3	x	
C 36		65	18	27.6	30	46.1	17	26.1		
C 37	63		9	14.2	33	52.3	21	33.3	x	
C 37		65	15	23.0	27	41.5	23	35.3		
C 38	63		18	28.5	33	52.3	12	19.0	x	
C 38		65	20	30.7	32	49.2	13	20.0		
C 39	63		19	30.1	27	42.8	17	26.9	x	
C 39		65	22	33.8	30	46.1	13	20.0		
C 40	63		14	22.2	22	34.9	27	42.8	x	
C 40		65	19	29.2	28	43.0	18	27.6		

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
C 41	63		18	28.5	33	52.3	12	19.0	x	
C 41		65	21	32.3	32	49.2	12	18.4		
C 42	63		17	26.9	30	47.6	16	25.3	x	
C 42		65	21	32.3	30	46.1	14	21.5		
C 43	63		20	31.7	27	42.8	16	25.3	x	
C 43		65	18	27.6	32	49.2	15	23.0		
C 44	63		16	25.3	23	36.5	24	38.0	x	
C 44		65	20	30.7	28	43.0	17	26.1		
C 45	63		17	26.9	24	38.0	22	34.9	x	
C 45		65	25	38.4	28	43.0	12	18.4		
C 46	63		16	25.3	23	36.5	24	38.0	x	
C 46		65	23	35.3	28	43.0	14	21.5		
C 47	63		20	31.7	24	38.0	19	30.1	x	
C 47		65	18	27.6	23	35.3	24	36.9		
C 48	63		23	36.5	29	46.0	11	17.4	x	
C 48		65	24	36.9	30	46.1	11	16.9		

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
C 49	63		22	34.9	27	42.8	14	22.2	x	
C 49		65	25	38.4	28	43.0	12	18.4		
C 50	63		23	36.5	23	36.5	17	26.9	x	
C 50		65	27	41.5	26	40.0	12	18.4		
C 51	63		22	34.9	24	38.0	17	26.9	x	
C 51		65	25	38.4	28	43.0	12	18.4		
C 52	63		11	17.4	24	38.0	28	44.4	x	
C 52		65	9	13.8	21	32.3	35	53.8		
C 53	63		9	14.2	30	47.6	24	38.0	x	
C 53		65	10	15.3	23	35.3	32	49.2		
C 54	63		9	14.2	22	34.9	32	50.7	x	
C 54		65	10	15.3	19	29.2	36	55.3		
C 55	63		9	14.2	29	46.0	25	39.6	x	
C 55		65	11	16.9	20	30.7	34	52.3		
D 1	63		8	12.6	28	44.4	27	42.8		x
D 1		65	12	18.4	15	23.0	38	58.4		

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
D 2	63		8	12.6	32	50.7	23	36.5	x	
D 2		65	15	23.0	29	44.6	21	32.3		
D 3	63		10	15.8	31	49.2	22	34.9	x	
D 3		65	15	23.0	36	55.3	14	21.5		
D 4	63		9	14.2	31	49.2	23	36.5		x
D 4		65	18	27.6	35	53.8	12	18.4		
D 5	63		12	19.0	30	47.6	21	33.3	x	
D 5		65	22	33.8	31	47.6	12	18.4		
D 6	63		14	22.2	27	42.8	22	34.9	x	
D 6		65	24	36.9	24	36.9	17	26.1		
D 7	63		15	23.8	32	50.7	16	25.3	x	
D 7		65	21	32.3	33	50.7	11	16.9		
D 8	63		17	26.9	30	47.6	16	25.3	x	
D 8		65	23	35.3	33	50.7	9	13.8		
D 9	63		15	23.8	30	47.6	18	28.5	x	
D 9		65	21	32.3	35	53.8	9	13.8		

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Brie'ly**		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
D 10	63		17	26.9	27	42.8	19	30.1	x	
D 10		65	22	33.8	33	50.7	10	15.3		
D 11	63		12	19.0	28	44.4	23	36.5	x	
D 11		65	18	27.6	34	52.3	13	20.0		
D 12	63		14	22.2	27	42.8	22	34.9	x	
D 12		65	13	20.0	33	50.7	19	29.2		
D 13	63		16	25.3	22	34.9	25	39.6		x
D 13		65	16	24.6	35	53.8	14	21.5		
D 14	63		11	17.4	26	41.2	26	41.2		x
D 14		65	24	36.9	30	46.1	11	16.9		
D 15	63		19	30.1	25	39.6	19	30.1	x	
D 15		65	29	44.6	27	41.5	9	13.8		
D 16	63		20	31.7	27	42.8	16	25.3	x	
D 16		65	31	47.6	25	38.4	9	13.8		
D 17	63		8	12.6	31	49.2	24	38.0	x	
D 17		65	13	20.0	33	50.7	19	29.2		

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
D 18	63		8	12.6	27	42.8	28	44.4	x	
D 18		65	13	20.0	32	49.2	20	30.7		
D 19	63		8	12.6	27	42.8	28	44.4	x	
D 19		65	13	20.0	34	52.3	18	27.6		
D 20	63		11	17.4	23	36.5	29	46.0	x	
D 20		65	13	20.0	33	50.7	19	29.2		
D 21	63		9	14.2	24	38.0	30	47.6	x	
D 21		65	14	21.5	33	50.7	18	27.6		
D 22	63		8	12.6	22	34.9	33	52.3	x	
D 22		65	13	20.0	25	38.4	27	41.5		
D 23	63		16	25.3	25	39.6	22	34.9	x	
D 23		65	18	27.6	34	52.3	13	20.0		
D 24	63		11	17.4	26	41.2	26	41.2	x	
D 24		65	15	23.0	29	44.6	21	32.3		
D 25	63		13	20.6	29	46.0	21	33.3	x	
D 25		65	18	27.6	31	47.6	16	24.6		

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
D 26	63		18	28.5	26	41.2	19	30.1	x	
D 26		65	19	29.2	28	43.0	18	27.6		
D 27	63		8	12.6	24	38.0	31	49.2	x	
D 27		65	13	20.0	28	43.0	24	36.9		
D 28	63		11	17.4	29	46.0	23	36.5	x	
D 28		65	17	26.1	27	41.5	21	32.3		
D 29	63		17	26.9	24	38.0	22	34.9	x	
D 29		65	20	30.7	31	47.6	14	21.5		
D 30	63		16	25.3	29	46.0	18	28.5	x	
D 30		65	20	30.7	27	41.5	18	27.6		
D 31	63		16	25.3	25	39.6	22	34.9	x	
D 31		65	24	36.9	29	44.6	12	18.4		
D 32	63		12	19.0	28	44.4	23	36.5	x	
D 32		65	20	30.7	28	43.0	17	26.1		
D 33	63		12	19.0	29	46.0	22	34.9	x	
D 33		65	21	32.3	29	44.6	15	23.0		

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Mrg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
D 34	63		10	15.8	29	46.0	24	38.0	x	
D 34		65	16	24.6	32	49.2	17	26.1		
D 35	63		10	15.8	28	44.4	25	39.6	x	
D 35		65	17	26.1	32	49.2	16	24.6		
D 36	63		9	14.2	26	41.2	28	44.4		x
D 36		65	21	32.2	24	36.9	20	30.7		
D 37	63		10	15.8	30	47.6	23	36.5		x
D 37		65	23	35.3	26	40.0	16	24.6		
D 38	63		10	15.8	33	52.3	20	31.7		x
D 38		65	25	38.4	23	35.3	17	26.1		
D 39	63		10	15.8	24	38.0	29	46.0		x
D 39		65	23	35.3	24	36.9	18	27.6		
D 40	63		18	28.5	32	50.7	13	20.6	x	
D 40		65	23	35.3	29	44.6	13	20.0		
D 41	63		17	26.9	30	47.6	16	25.3	x	
D 41		65	24	36.9	25	38.4	16	24.6		

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
D 42	63		9	14.2	21	33.3	33	52.3	x	
D 42		65	17	26.1	23	35.3	25	38.4		
D 43	63		9	14.2	22	34.9	32	50.7	x	
D 43		65	16	24.6	24	36.9	25	38.4		
D 44	63		10	15.8	28	44.4	25	39.6	x	
D 44		65	18	27.6	30	46.1	17	26.1		
D 45	63		12	19.0	25	39.6	26	41.2	x	
D 45		65	19	29.2	29	44.6	17	26.1		
D 46	63		8	12.6	27	42.8	28	44.4	x	
D 46		65	11	16.9	22	33.8	32	49.2		
D 47	63		8	12.6	20	31.7	35	55.5	x	
D 47		65	10	15.3	16	24.6	39	60.0		
D 48	63		8	12.6	30	47.6	25	39.6	x	
D 48		65	12	18.4	25	38.4	28	43.0		
D 49	63		8	12.6	22	34.9	33	52.3	x	
D 49		65	12	18.4	25	38.4	28	43.0		

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
D 50	63		8	12.6	24	38.0	31	49.2	x	
D 50		65	11	16.9	35	53.8	19	29.2		
D 51	63		11	17.4	18	28.5	34	53.9		x
D 51		65	16	24.6	29	44.6	20	30.7		
D 52	63		11	17.4	14	22.2	38	60.3		x
D 52		65	18	27.6	23	35.3	24	36.9		
D 53	63		9	14.2	18	28.5	36	57.1	x	
D 53		65	11	16.9	22	33.8	32	49.2		
D 54	63		8	12.6	20	31.7	35	55.5	x	
D 54		65	13	20.0	20	30.7	32	49.2		
D 55	63		9	14.2	20	31.7	34	53.9	x	
D 55		65	12	18.4	10	15.3	43	66.1		
D 56	63		8	12.6	22	34.9	33	52.3	x	
D 56		65	12	18.4	20	30.7	33	50.7		
E 1	63		9	14.2	23	36.5	31	49.2	x	
E 1		65	10	15.3	17	26.1	38	58.4		

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
E 2	63		8	12.6	29	46.0	26	41.2		x
E 2		65	12	18.4	40	61.5	13	20.0		
E 3	63		17	26.9	33	52.3	13	20.6	x	
E 3		65	15	23.0	39	60.0	11	16.9		
E 4	63		18	28.5	26	41.2	19	30.1	x	
E 4		65	17	26.1	35	53.8	13	20.0		
E 5	63		13	20.6	27	42.8	23	36.5	x	
E 5		65	15	23.0	33	50.7	17	26.1		
E 6	63		11	17.4	28	44.4	24	38.0	x	
E 6		65	18	27.6	29	44.6	18	27.6		
E 7	63		14	22.2	32	50.7	17	26.9	x	
E 7		65	23	35.3	28	43.0	14	21.5		
E 8	63		10	15.8	14	22.2	39	61.9	x	
E 8		65	9	13.8	12	18.4	44	67.6		
E 9	63		10	15.8	22	34.9	31	49.2	x	
E 9		65	9	13.8	22	33.8	34	52.3		

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Brierly**		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
E 10	63		10	15.8	25	39.6	28	44.4	x	
E 10		65	8	12.3	32	49.2	25	38.4		
E 11	63		9	14.2	32	50.7	22	34.9	x	
E 11		65	9	13.8	37	56.9	19	29.2		
E 12	63		9	14.2	28	44.4	26	41.2	x	
E 12		65	14	21.5	30	46.1	21	32.3		
E 13	63		11	17.4	22	34.9	30	47.6		x
E 13		65	16	24.6	33	50.7	16	24.6		
E 14	63		12	19.0	25	39.6	26	41.2	x	
E 14		65	18	27.6	26	40.0	21	32.3		
E 15	63		8	12.6	34	53.9	21	33.3	x	
E 15		65	14	21.5	28	43.0	23	35.3		
E 16	63		9	14.2	26	41.2	28	44.4	x	
E 16		65	9	13.8	28	43.0	28	43.0		
E 17	63		9	14.2	32	50.7	22	34.9	x	
E 17		65	10	15.3	31	47.6	24	36.9		

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
E 18	63		9	14.2	30	47.6	24	38.0	x	
E 18		65	10	15.3	31	47.6	24	36.9		
E 19	63		9	14.2	22	34.9	32	50.7	x	
E 19		65	8	12.3	28	43.0	29	44.6		
E 20	63		10	15.8	24	38.0	29	46.0	x	
E 20		65	11	16.9	35	53.8	19	29.2		
E 21	63		12	19.0	25	39.6	26	41.2	x	
E 21		65	12	18.4	34	52.3	19	29.2		
E 22	63		15	23.8	27	42.8	21	33.3	x	
E 22		65	18	27.6	31	47.6	16	24.6		
E 23	63		11	17.4	18	28.5	34	53.9	x	
E 23		65	10	15.3	16	24.6	39	60.0		
E 24	63		9	14.2	20	31.7	34	53.9	x	
E 24		65	9	13.8	17	26.1	39	60.0		
E 25	63		11	17.4	30	47.6	22	34.9	x	
E 25		65	17	26.1	29	44.6	19	29.2		

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
E 26	63		11	17.4	31	49.2	21	33.3		x
E 26		65	21	32.3	33	50.7	11	16.9		
E 27	63		9	14.2	34	53.9	20	31.7		x
E 27		65	21	32.3	36	55.3	8	12.3		
E 28	63		9	14.2	27	42.8	27	42.8	x	
E 28		65	20	30.7	22	33.8	23	35.3		
E 29	63		9	14.2	25	39.6	29	46.0		x
E 29		65	20	30.7	30	46.1	15	23.0		
E 30	63		20	31.7	30	47.6	13	20.6	x	
E 30		65	33	50.7	22	33.8	10	15.3		
E 31	63		9	14.2	23	36.5	31	49.2		x
E 31		65	15	23.0	34	52.3	16	24.6		
E 32	63		9	14.2	25	39.6	29	46.0	x	
E 32		65	17	26.1	29	44.6	19	29.2		
E 33	63		11	17.4	18	28.5	34	53.9	x	
E 33		65	16	24.6	27	41.5	22	33.8		

APPENDIX Q --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Mfg.	S. C.	No.	%	No.	%	No.	%	Retain	Reject
E 34	63		9	14.2	26	41.2	28	44.4	x	
E 34		65	11	16.9	14	21.5	40	61.5		
E 35	63		8	12.6	26	41.2	29	46.0	x	
E 35		65	12	18.4	23	35.3	30	46.1		
E 36	63		9	14.2	22	34.9	32	50.7	x	
E 36		65	15	23.0	29	44.6	21	32.3		
E 37	63		9	14.2	20	31.7	34	53.9		x
E 37		65	15	23.0	30	46.1	20	30.7		
E 38	63		11	17.4	12	19.0	40	63.4	x	
E 38		65	18	27.6	19	29.2	28	43.0		
E 39	63		11	17.4	19	30.1	33	52.3	x	
E 39		65	11	16.9	11	16.9	43	66.1		
E 40	63		13	20.6	16	25.3	34	53.9	x	
E 40		65	10	15.3	10	15.3	45	69.2		
E 41	63		11	17.4	19	30.1	33	52.3		
E 41		65	11	16.9	10	15.3	44	67.6		

APPENDIX R

SIGNIFICANCE OF RESPONSE DATA FROM SUPERVISORS AND OPERATORS

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
A 1	67		17	25.3	21	31.3	29	43.2	x	
A 1		61	13	21.3	13	21.3	35	57.3		
A 2	67		24	35.8	29	43.2	14	20.8	x	
A 2		61	23	37.7	29	47.5	9	14.7		
A 3	67		25	37.3	30	44.7	12	17.9	x	
A 3		61	23	37.7	27	44.2	11	18.0		
A 4	67		14	20.8	29	43.2	24	35.8	x	
A 4		61	17	27.8	28	45.9	16	26.2		

*Supervisor or Operator.

**Includes data from Column 1.

APPENDIX R --Continued

Subject Matter	Category* No.		Degree of Emphasis Discussed Briefly**		Discussed in General		Discussed in Detail		Hypothesis	
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
A 5	67		15	22.3	30	44.7	22	32.8	x	
A 5		61	23	37.7	25	40.9	13	21.3		
A 6	67		26	38.8	31	46.2	10	14.9	x	
A 6		61	26	42.6	23	37.7	12	19.6		
A 7	67		21	31.3	30	44.7	16	23.8	x	
A 7		61	21	34.4	23	37.7	17	27.8		
A 8	67		19	28.3	29	43.2	19	28.3		x
A 8		61	30	49.1	21	34.4	10	16.3		
A 9	67		27	40.2	26	38.8	14	20.8	x	
A 9		61	28	45.9	24	39.3	9	14.7		
A 10	67		25	37.3	28	41.7	14	20.8	x	
A 10		61	24	39.3	26	42.6	11	18.0		
A 11	67		9	13.4	34	50.7	24	35.8	x	
A 11		61	16	26.2	31	50.8	14	22.9		
A 12	67		23	34.3	25	37.3	19	28.3	x	
A 12		61	21	34.4	31	50.8	9	14.7		

APPENDIX R --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
A 13	67		21	31.3	28	41.7	18	26.8	x	
A 13		61	22	36.0	22	36.0	17	27.8		
A 14	67		21	31.3	30	44.7	16	23.8	x	
A 14		61	26	42.6	18	29.5	17	27.8		
A 15	67		30	44.7	26	38.8	11	16.4	x	
A 15		61	35	57.3	16	26.2	10	16.3		
A 16	67		22	32.8	28	41.7	17	25.3		x
A 16		61	33	54.0	15	24.5	13	21.3		
A 17	67		37	55.2	22	32.8	8	11.9	x	
A 17		61	30	49.1	20	32.7	11	18.0		
A 18	67		26	38.8	26	38.8	15	22.3	x	
A 18		61	27	44.2	23	37.7	11	18.0		
A 19	67		28	41.7	26	38.8	13	19.4	x	
A 19		61	27	44.2	23	37.7	11	18.0		
A 20	67		26	38.8	26	38.8	15	22.3	x	
A 20		61	17	27.8	22	36.0	22	36.0		

APPENDIX R --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
A 21	67		41	61.1	18	26.8	8	11.9	x	
A 21		61	32	52.4	19	31.1	10	16.3		
A 22	67		40	59.7	19	28.3	8	11.9	x	
A 22		61	36	59.0	16	26.2	9	14.7		
A 23	67		40	59.7	16	23.8	11	16.4	x	
A 23		61	33	54.0	20	32.7	8	13.1		
A 24	67		27	40.2	26	38.8	14	20.8	x	
A 24		61	20	32.7	29	47.5	12	19.6		
A 25	67		24	35.8	23	34.3	20	29.8	x	
A 25		61	18	29.5	27	44.2	16	26.2		
A 26	67		25	37.3	23	34.3	19	28.3	x	
A 26		61	26	42.6	25	40.9	10	16.3		
A 27	67		30	44.7	24	35.8	13	19.4	x	
A 27		61	30	49.1	15	24.5	16	26.2		
A 28	67		25	37.3	23	34.3	19	28.3	x	
A 28		61	32	52.4	15	24.5	14	22.9		

APPENDIX R --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
A 29	67		24	35.8	27	40.2	16	23.8	x	
A 29		61	22	36.0	24	39.3	15	24.5		
A 30	67		8	11.9	34	50.7	25	37.3		x
A 30		61	16	26.2	18	29.5	27	44.2		
A 31	67		25	37.3	27	40.2	15	22.3	x	
A 31		61	19	31.1	30	49.1	12	19.6		
A 32	67		31	46.2	25	37.3	11	16.4	x	
A 32		61	22	36.0	24	39.3	15	24.5		
A 33	67		31	46.2	21	31.3	15	22.3	x	
A 33		61	24	39.3	27	44.2	10	16.3		
A 34	67		29	43.2	26	38.8	12	17.9	x	
A 34		61	25	40.9	22	36.0	14	22.9		
A 35	67		8	11.9	24	35.8	35	52.2		x
A 35		61	17	27.8	23	37.7	21	34.4		
A 36	67		9	13.4	30	44.7	28	41.7	x	
A 36		61	13	21.3	28	45.9	20	32.7		

APPENDIX R --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
A 37	67		8	11.9	28	41.7	31	46.2	x	
A 37		61	13	21.3	29	47.5	19	31.1		
A 38	67		16	23.8	26	38.8	25	37.3	x	
A 38		61	22	36.0	18	29.5	21	34.4		
A 39	67		27	40.2	27	40.2	13	19.4	x	
A 39		61	30	49.1	19	31.1	12	19.6		
A 40	67		8	11.9	31	46.2	28	41.7		x
A 40		61	18	29.5	17	27.8	26	42.6		
A 41	67		8	11.9	25	37.3	34	50.7	x	
A 41		61	14	22.9	13	21.3	34	55.7		
B 1	67		12	17.9	26	38.8	29	43.2	x	
B 1		61	12	19.6	21	34.4	28	45.9		
B 2	67		19	28.3	35	52.2	13	19.4	x	
B 2		61	20	32.7	26	42.6	15	24.5		
B 3	67		20	29.8	28	41.7	19	28.3	x	
B 3		61	16	26.2	30	49.1	15	24.5		

APPENDIX R --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
B 4	67		22	32.8	32	47.7	13	19.4	x	
B 4		61	20	32.7	25	40.9	16	26.2		
B 5	67		19	28.3	32	47.7	16	23.8	x	
B 5		61	18	29.5	27	44.2	16	26.2		
B 6	67		18	26.8	33	49.2	16	23.8	x	
B 6		61	19	31.1	25	40.9	17	27.8		
B 7	67		21	31.3	33	49.2	13	19.4	x	
B 7		61	20	32.7	23	37.7	18	29.5		
B 8	67		10	14.9	16	23.8	41	61.1		x
B 8		61	11	18.0	26	42.6	24	39.3		
B 9	67		10	14.9	23	34.3	34	50.7	x	
B 9		61	11	18.0	27	44.2	23	37.7		
B 10	67		12	17.9	27	40.2	28	41.7	x	
B 10		61	15	24.5	26	42.6	20	32.7		
B 11	67		12	17.9	26	38.8	29	43.2	x	
B 11		61	16	26.2	27	44.2	18	29.5		

APPENDIX R --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
B 12	67		17	25.3	30	44.7	20	29.8	x	
B 12		61	21	34.4	25	40.9	15	24.5		
B 13	67		16	23.8	26	38.8	25	37.3	x	
B 13		61	25	40.9	22	36.0	14	22.9		
B 14	67		22	32.8	31	46.2	14	20.8	x	
B 14		61	28	45.9	25	40.9	8	13.1		
B 15	67		8	11.9	32	47.7	27	40.2	x	
B 15		61	15	24.5	18	29.5	28	45.9		
B 16	67		10	14.9	30	44.7	27	40.2	x	
B 16		61	15	24.5	26	42.6	20	32.7		
B 17	67		12	17.9	29	43.2	26	38.8	x	
B 17		61	15	24.5	27	44.2	19	31.1		
B 18	67		10	14.9	30	44.7	27	40.2	x	
B 18		61	17	27.8	21	34.4	23	37.7		
B 19	67		15	22.3	29	43.2	23	34.3	x	
B 19		61	20	32.7	24	39.3	17	27.8		

APPENDIX R --Continued

Subject Matter	Category* No.		Degree of Emphasis Discussed Briefly**		Discussed in General		Discussed in Detail		Hypothesis	
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
B 20	67		16	23.8	31	46.2	20	29.8	x	
B 20		61	19	31.1	28	45.9	14	22.9		
B 21	67		15	22.3	25	37.3	27	40.2	x	
B 21		61	25	40.9	20	32.7	16	26.2		
B 22	67		17	25.3	25	37.3	25	37.3	x	
B 22		61	25	40.9	20	32.7	16	26.2		
B 23	67		21	31.3	23	34.3	23	34.3	x	
B 23		61	27	44.2	20	32.7	14	22.9		
B 24	67		19	28.3	21	31.3	27	40.2	x	
B 24		61	20	32.7	23	37.7	18	29.5		
B 25	67		14	20.8	29	43.2	24	35.8	x	
B 25		61	15	24.5	20	32.7	26	42.6		
B 26	67		22	32.8	28	41.7	17	25.3	x	
B 26		61	27	44.2	25	40.9	9	14.7		
B 27	67		20	29.8	28	41.7	19	28.3	x	
B 27		61	28	45.9	22	36.0	11	18.0		

APPENDIX R --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
B 28	67		8	11.9	25	37.3	34	50.7		x
B 28		61	22	36.0	20	32.7	19	31.1		
B 29	67		10	14.9	24	35.8	33	49.2		x
B 29		61	15	24.5	29	47.5	17	27.8		
B 30	67		19	28.3	24	35.8	24	35.8	x	
B 30		61	15	24.5	26	42.6	20	32.7		
B 31	67		9	13.4	25	37.3	33	49.2	x	
B 31		61	14	22.9	23	37.7	24	39.3		
B 32	67		9	13.4	22	32.8	36	53.7	x	
B 32		61	12	19.6	22	36.0	27	44.2		
B 33	67		9	13.4	27	40.2	31	46.2	x	
B 33		61	10	16.3	26	42.6	25	40.9		
B 34	67		11	16.4	26	38.8	30	44.7	x	
B 34		61	9	14.7	28	45.9	24	39.3		
B 35	67		8	11.9	24	35.8	35	52.2	x	
B 35		61	15	24.5	20	32.7	26	42.6		

APPENDIX R --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
B 36	67		8	11.9	30	44.7	29	43.2		x
B 36		61	19	31.1	18	29.5	24	39.3		
B 37	67		15	22.3	34	50.7	18	26.8	x	
B 37		61	14	22.9	33	54.0	14	22.9		
B 38	67		15	22.3	32	47.7	20	29.8	x	
B 38		61	15	24.5	31	50.8	15	24.5		
B 39	67		20	29.8	31	46.2	16	23.8	x	
B 39		61	16	26.2	31	50.8	14	22.9		
B 40	67		20	29.8	33	49.2	14	20.8	x	
B 40		61	18	29.5	30	49.1	13	21.3		
B 41	67		13	19.4	32	47.7	22	32.8	x	
B 41		61	18	29.5	22	36.0	21	34.4		
B 42	67		23	34.3	29	43.2	15	22.3	x	
B 42		61	19	31.1	23	37.7	19	31.1		
B 43	67		17	25.3	28	41.7	22	32.8	x	
B 43		61	15	24.5	22	36.0	24	39.3		

APPENDIX R --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
B 44	67		8	11.9	30	44.7	29	43.2	x	
B 44		61	13	21.3	19	31.1	29	47.5		
B 45	67		18	26.8	32	47.7	17	25.3	x	
B 45		61	16	26.2	27	44.2	18	29.5		
B 46	67		14	20.8	29	43.2	24	35.8	x	
B 46		61	19	31.1	23	37.7	19	31.1		
B 47	67		12	17.9	35	52.2	20	29.8	x	
B 47		61	15	24.5	27	44.2	19	31.1		
B 48	67		13	19.4	26	38.8	28	41.7	x	
B 48		61	18	29.5	18	29.5	25	40.9		
B 49	67		19	28.3	22	32.8	26	38.8	x	
B 49		61	17	27.8	21	34.4	23	37.7		
B 50	67		12	17.9	29	43.2	26	38.8		x
B 50		61	10	16.3	13	21.3	38	62.2		
B 51	67		8	11.9	25	37.3	34	50.7	x	
B 51		61	11	18.0	12	19.6	38	62.2		

APPENDIX R --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
C 1	67		11	16.4	29	43.2	27	40.2		
C 1		61	11	18.0	11	18.0	39	63.9		x
C 2	67		17	25.3	31	46.2	19	28.3		
C 2		61	10	16.3	29	47.5	22	36.0	x	
C 3	67		24	35.8	30	44.7	13	19.4		
C 3		61	20	32.7	22	36.0	19	31.1	x	
C 4	67		20	29.8	34	50.7	13	19.4		
C 4		61	22	36.0	23	37.7	16	26.2	x	
C 5	67		26	38.8	28	41.7	13	19.4		
C 5		61	17	27.8	22	36.0	22	36.0	x	
C 6	67		20	29.8	31	46.2	16	23.8		
C 6		61	20	32.7	28	45.9	13	21.3	x	
C 7	67		19	28.3	32	47.7	16	23.8		
C 7		61	20	32.7	28	45.9	13	21.3	x	
C 8	67		19	28.3	32	47.7	16	23.8		
C 8		61	19	31.1	32	52.4	10	16.3	x	

APPENDIX R --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
C 9	67		18	26.8	34	50.7	15	22.3	x	
C 9		61	18	29.5	32	52.4	11	18.0		
C 10	67		22	32.8	29	43.2	16	23.8	x	
C 10		61	20	32.7	29	47.5	12	19.6		
C 11	67		21	31.3	30	44.7	16	23.8	x	
C 11		61	18	29.5	32	52.4	11	18.0		
C 12	67		24	35.8	28	41.7	15	22.3	x	
C 12		61	19	31.1	32	52.4	10	16.3		
C 13	67		24	35.8	25	37.3	18	26.8	x	
C 13		61	17	27.8	29	47.5	15	24.5		
C 14	67		26	38.8	27	40.2	14	20.8	x	
C 14		61	19	31.1	28	45.9	14	22.9		
C 15	67		25	37.3	29	43.2	13	19.4	x	
C 15		61	19	31.1	26	42.6	16	26.2		
C 16	67		25	37.3	29	43.2	13	19.4	x	
C 16		61	21	34.4	27	44.2	13	21.3		

APPENDIX R -- Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
C 17	67		8	11.9	20	29.8	39	58.2	x	
C 17		61	15	24.5	21	34.4	25	40.9		
C 18	67		11	16.4	30	44.7	26	38.8	x	
C 18		61	13	21.3	29	47.5	19	31.1		
C 19	67		17	25.3	30	44.7	20	29.8	x	
C 19		61	17	27.8	31	50.8	13	21.3		
C 20	67		14	20.8	33	49.2	20	29.8	x	
C 20		61	15	24.5	26	42.6	20	32.7		
C 21	67		11	16.4	32	47.7	24	35.8	x	
C 21		61	18	29.5	28	45.9	15	24.5		
C 22	67		13	19.4	30	44.7	24	35.8	x	
C 22		61	17	27.8	21	34.4	23	37.7		
C 23	67		20	29.8	29	43.2	18	26.8	x	
C 23		61	20	32.7	24	39.3	17	27.8		
C 24	67		21	31.3	31	46.2	15	22.3	x	
C 24		61	22	36.0	21	34.4	18	29.5		

APPENDIX R --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
C 25	67		17	25.3	30	44.7	20	29.8	x	
C 25		61	18	29.5	22	36.0	21	34.4		
C 26	67		22	32.8	32	47.7	13	19.4	x	
C 26		61	19	31.1	24	39.3	18	29.5		
C 27	67		23	34.3	33	49.2	11	16.4	x	
C 27		61	22	36.0	25	40.9	14	22.9		
C 28	67		29	43.2	29	43.2	9	13.4	x	
C 28		61	25	40.9	20	32.7	16	26.2		
C 29	67		19	28.3	35	52.2	13	19.4	x	
C 29		61	22	36.0	22	36.0	17	27.8		
C 30	67		17	25.3	31	46.2	19	28.3	x	
C 30		61	15	24.5	27	44.2	19	31.1		
C 31	67		24	35.8	32	47.7	11	16.4	x	
C 31		61	23	37.7	24	39.3	14	22.9		
C 32	67		17	25.3	36	53.7	14	20.8	x	
C 32		61	18	29.5	32	52.4	11	18.0		

APPENDIX R --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
C 33	67		23	34.3	36	53.7	8	11.9	x	
C 33		61	19	31.1	29	47.5	13	21.3		
C 34	67		21	31.3	33	49.2	13	19.4	x	
C 34		61	19	31.1	24	39.3	18	29.5		
C 35	67		17	25.3	32	47.7	18	26.8	x	
C 35		61	17	27.8	22	36.0	22	36.0		
C 36	67		20	29.8	30	44.7	17	25.3	x	
C 36		61	20	32.7	23	37.7	18	29.5		
C 37	67		11	16.4	32	47.7	24	35.8	x	
C 37		61	13	21.3	25	40.9	23	37.7		
C 38	67		21	31.3	34	50.7	12	17.9	x	
C 38		61	17	27.8	31	50.8	13	21.3		
C 39	67		21	31.3	33	49.2	13	19.4	x	
C 39		61	20	32.7	24	39.3	17	27.8		
C 40	67		16	23.8	29	43.2	22	32.8	x	
C 40		61	17	27.8	22	36.0	22	36.0		

APPENDIX R --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
C 41	67		18	26.8	36	53.7	13	19.4	x	
C 41		61	19	31.1	29	47.5	13	21.3		
C 42	67		19	28.3	35	52.2	13	19.4	x	
C 42		61	19	31.1	26	42.6	16	26.2		
C 43	67		20	29.8	35	52.2	12	17.9	x	
C 43		61	18	29.5	25	40.9	18	29.5		
C 44	67		17	25.3	29	43.2	21	31.3	x	
C 44		61	18	29.5	23	37.7	20	32.7		
C 45	67		18	26.8	32	47.7	17	25.3	x	
C 45		61	20	32.7	23	37.7	18	29.5		
C 46	67		17	25.3	32	47.7	18	26.8	x	
C 46		61	20	32.7	22	36.0	19	31.1		
C 47	67		20	29.8	26	38.8	21	31.3	x	
C 47		61	18	29.5	19	31.1	24	39.3		
C 48	67		23	34.3	31	46.2	13	19.4	x	
C 48		61	22	36.0	26	42.6	13	21.3		

APPENDIX R --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
C 49	67		23	34.3	32	47.7	12	17.9	x	
C 49		61	22	36.0	24	39.3	15	24.5		
C 50	67		25	37.3	31	46.2	11	16.4	x	
C 50		61	24	39.3	19	31.1	18	29.5		
C 51	67		21	31.3	34	50.7	12	17.9	x	
C 51		61	24	39.3	20	32.7	17	27.8		
C 52	67		9	13.4	22	32.8	36	53.7	x	
C 52		61	10	16.3	23	37.7	28	45.9		
C 53	67		12	17.9	27	40.2	28	41.7	x	
C 53		61	8	13.1	23	37.7	30	49.1		
C 54	67		8	11.9	30	44.7	29	43.2		x
C 54		61	11	18.0	14	22.9	36	59.0		
C 55	67		10	14.9	27	40.2	30	44.7	x	
C 55		61	10	16.3	21	34.4	30	49.1		
D 1	67		13	19.4	20	29.8	34	50.7	x	
D 1		61	9	14.7	21	34.4	31	50.8		

APPENDIX R --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
D 2	67		12	17.9	27	40.2	28	41.7	x	
D 2		61	9	14.7	33	54.0	19	31.1		
D 3	67		15	22.3	36	53.7	16	23.8	x	
D 3		61	10	16.3	34	55.7	17	27.8		
D 4	67		16	23.8	33	49.2	18	26.8	x	
D 4		61	13	21.3	33	54.0	15	24.5		
D 5	67		19	28.3	31	46.2	17	25.3	x	
D 5		61	16	26.2	27	44.2	18	29.5		
D 6	67		19	28.3	29	43.2	19	28.3	x	
D 6		61	20	32.7	21	34.4	20	32.7		
D 7	67		18	26.8	36	53.7	13	19.4	x	
D 7		61	19	31.1	28	45.9	14	22.9		
D 8	67		19	28.3	36	53.7	12	17.9	x	
D 8		61	20	32.7	27	44.2	14	22.9		
D 9	67		20	29.8	33	49.2	14	20.8	x	
D 9		61	14	22.9	33	54.0	14	22.9		

APPENDIX R --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
D 10	67		23	34.3	32	47.7	12	17.9	x	
D 10		61	17	27.8	28	45.9	16	26.2		
D 11	67		15	22.3	34	50.7	18	26.8	x	
D 11		61	14	22.9	31	50.8	16	26.2		
D 12	67		14	20.8	31	46.2	22	32.8	x	
D 12		61	14	22.9	30	49.1	17	27.8		
D 13	67		19	28.3	29	43.2	19	28.3	x	
D 13		61	11	18.0	31	50.8	19	31.1		
D 14	67		15	22.3	36	53.7	16	23.8	x	
D 14		61	19	31.1	23	37.7	19	31.1		
D 15	67		23	34.3	33	49.2	11	16.4	x	
D 15		61	25	40.9	23	37.7	13	21.3		
D 16	67		25	37.3	32	47.7	10	14.9	x	
D 16		61	26	42.6	22	36.0	13	21.3		
D 17	67		9	13.4	34	50.7	24	35.8	x	
D 17		61	10	16.3	34	55.7	17	27.8		

APPENDIX R --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
D 18	67		10	14.9	28	41.7	29	43.2	x	
D 18		61	11	18.0	32	52.4	18	29.5		
D 19	67		8	11.9	32	47.7	27	40.2	x	
D 19		61	11	18.0	32	52.4	18	29.5		
D 20	67		10	14.9	31	46.2	26	38.8	x	
D 20		61	13	21.3	28	45.9	20	32.7		
D 21	67		10	14.9	28	41.7	29	43.2	x	
D 21		61	13	21.3	30	49.1	18	29.5		
D 22	67		8	11.9	27	40.2	32	47.7	x	
D 22		61	16	26.2	24	39.3	21	34.4		
D 23	67		15	22.3	34	50.7	18	26.8	x	
D 23		61	18	29.5	26	42.6	17	27.8		
D 24	67		10	14.9	31	46.2	26	38.8	x	
D 24		61	15	24.5	27	44.2	19	31.1		
D 25	67		12	17.9	35	52.2	20	29.8	x	
D 25		61	19	31.1	26	42.6	16	26.2		

APPENDIX R --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
D 26	67		23	34.3	24	35.8	20	29.8	x	
D 26		61	14	22.9	31	50.8	16	26.2		
D 27	67		9	13.4	22	32.8	36	53.7		x
D 27		61	15	24.5	26	42.6	20	32.7		
D 28	67		11	16.4	26	38.8	30	44.7		x
D 28		61	17	27.8	30	49.1	14	22.9		
D 29	67		18	26.8	29	43.2	20	29.8	x	
D 29		61	20	32.7	26	42.6	15	24.5		
D 30	67		16	23.8	32	47.7	19	28.3	x	
D 30		61	19	31.1	26	42.6	16	26.2		
D 31	67		20	29.8	28	41.7	19	28.3	x	
D 31		61	21	34.4	25	40.9	15	24.5		
D 32	67		16	23.8	28	41.7	23	34.3	x	
D 32		61	17	27.8	29	47.5	15	24.5		
D 33	67		16	23.8	31	46.2	20	29.8	x	
D 33		61	18	29.5	27	44.2	16	26.2		

APPENDIX R --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
D 34	67		13	19.4	27	40.2	27	40.2		x
D 34		61	15	24.5	34	55.7	12	19.6		
D 35	67		12	17.9	29	43.2	26	38.8	x	
D 35		61	16	26.2	29	47.5	16	26.2		
D 36	67		13	19.4	26	38.8	28	41.7	x	
D 36		61	19	31.1	23	37.7	19	31.1		
D 37	67		14	20.8	29	43.2	24	35.8	x	
D 37		61	20	32.7	27	44.2	14	22.9		
D 38	67		16	23.8	27	40.2	24	35.8	x	
D 38		61	20	32.7	28	45.9	13	21.3		
D 39	67		15	22.3	25	37.3	27	40.2	x	
D 39		61	17	27.8	25	40.9	19	31.1		
D 40	67		17	25.3	35	52.2	15	22.3	x	
D 40		61	20	32.7	26	42.6	15	24.5		
D 41	67		19	28.3	32	47.7	16	23.8	x	
D 41		61	22	36.0	22	36.0	17	27.8		

APPENDIX R --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
D 42	67		13	19.4	25	37.3	29	43.2	x	
D 42		61	15	24.5	19	31.1	27	44.2		
D 43	67		11	16.4	27	40.2	29	43.2	x	
D 43		61	14	22.9	20	32.7	27	44.2		
D 44	67		12	17.9	34	50.7	21	31.3	x	
D 44		61	16	26.2	22	36.0	23	37.7		
D 45	67		16	23.8	33	49.2	18	26.8	x	
D 45		61	14	22.9	23	37.7	24	39.3		
D 46	67		9	13.4	27	40.2	31	46.2	x	
D 46		61	10	16.3	21	34.4	30	49.1		
D 47	67		9	13.4	20	29.8	38	56.7	x	
D 47		61	9	14.7	15	24.5	37	60.6		
D 48	67		8	11.9	32	47.7	27	40.2	x	
D 48		61	11	18.0	22	36.0	28	45.9		
D 49	67		9	13.4	22	32.8	36	53.7	x	
D 49		61	12	19.6	23	37.7	26	42.6		

APPENDIX R --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
D 50	67		9	13.4	25	37.3	33	49.2	x	
D 50		61	12	19.6	31	50.8	18	29.5		
D 51	67		12	17.9	23	34.3	32	47.7	x	
D 51		61	16	26.2	26	42.6	19	31.1		
D 52	67		9	13.4	18	26.8	40	59.7	x	
D 52		61	16	26.2	19	31.1	26	42.6		
D 53	67		8	11.9	18	26.8	41	61.1	x	
D 53		61	11	18.0	21	34.4	29	47.5		
D 54	67		9	13.2	19	27.9	40	58.8	x	
D 54		61	12	19.6	20	32.7	29	47.5		
D 55	67		11	16.4	18	26.8	38	56.7	x	
D 55		61	12	19.6	17	27.8	32	52.4		
D 56	67		10	14.9	23	34.3	34	50.7	x	
D 56		61	11	18.0	10	16.3	40	65.5		
E 1	67		10	14.9	26	38.8	31	46.2	x	
E 1		61	9	14.7	14	22.9	38	62.2		

APPENDIX R --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
E 2	67		13	19.4	32	47.7	22	32.8	x	
E 2		61	8	13.1	34	55.7	19	31.1		
E 3	67		19	28.3	33	49.2	15	22.3	x	
E 3		61	14	22.9	37	60.6	10	16.3		
E 4	67		19	28.3	33	49.2	15	22.3	x	
E 4		61	15	24.5	29	47.5	17	27.8		
E 5	67		11	16.4	33	49.2	23	34.3	x	
E 5		61	16	26.2	27	44.2	18	29.5		
E 6	67		14	20.8	33	49.2	20	29.8	x	
E 6		61	16	26.2	25	40.9	20	32.7		
E 7	67		18	26.8	34	50.7	15	22.3	x	
E 7		61	20	32.7	26	42.6	15	24.5		
E 8	67		8	11.9	16	23.8	43	64.1	x	
E 8		61	9	14.7	11	18.0	41	67.2		
E 9	67		8	11.9	24	35.8	35	52.2	x	
E 9		61	12	19.6	19	31.1	30	49.1		

APPENDIX R --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
E 10	67		10	14.9	27	40.2	30	44.7	x	
E 10		61	8	13.1	33	54.0	20	32.7		
E 11	67		8	11.9	31	46.2	28	41.7		x
E 11		61	11	18.0	37	60.6	13	21.3		
E 12	67		10	14.9	25	37.3	32	47.7	x	
E 12		61	11	18.0	32	52.4	18	29.5		
E 13	67		14	20.8	29	43.2	24	35.8	x	
E 13		61	15	24.5	24	39.3	22	36.0		
E 14	67		13	19.4	29	43.2	25	37.3	x	
E 14		61	16	26.2	24	39.3	21	34.4		
E 15	67		9	13.4	33	49.2	25	37.3	x	
E 15		61	15	24.5	25	40.9	21	34.4		
E 16	67		8	11.9	28	41.7	31	46.2	x	
E 16		61	10	16.3	27	44.2	24	39.3		
E 17	67		10	14.9	29	43.2	28	41.7	x	
E 17		61	9	14.7	30	49.1	22	36.0		

APPENDIX R --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
E 18	67		12	17.9	33	49.2	22	32.8	x	
E 18		61	8	13.1	26	42.6	27	44.2		
E 19	67		8	11.9	24	35.8	35	52.2	x	
E 19		61	8	13.1	26	42.6	27	44.2		
E 20	67		9	13.4	28	41.7	30	44.7	x	
E 20		61	13	21.3	29	47.5	19	31.1		
E 21	67		14	20.8	26	38.8	27	40.2	x	
E 21		61	14	22.9	26	42.6	21	34.4		
E 22	67		17	25.3	27	40.2	23	34.3	x	
E 22		61	17	27.8	28	45.9	16	26.2		
E 23	67		8	11.9	20	29.8	39	58.2	x	
E 23		61	12	19.6	15	24.5	34	55.7		
E 24	67		8	11.9	21	31.3	38	56.7	x	
E 24		61	11	18.0	15	24.5	35	57.3		
E 25	67		10	14.9	35	52.2	22	32.8	x	
E 25		61	17	27.8	24	39.3	20	32.7		

APPENDIX R --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
E 26	67		13	19.4	32	47.7	22	32.8	x	
E 26		61	19	31.1	32	52.4	10	16.3		
E 27	67		11	16.4	40	59.7	16	23.8	x	
E 27		61	20	32.7	31	50.8	10	16.3		
E 28	67		8	11.9	30	44.7	29	43.2		x
E 28		61	19	31.1	24	39.3	18	29.5		
E 29	67		10	14.9	29	43.2	28	41.7	x	
E 29		61	19	31.1	24	39.3	18	29.5		
E 30	67		25	37.3	25	37.3	17	25.3	x	
E 30		61	25	40.9	26	42.6	10	16.3		
E 31	67		9	13.4	28	41.7	30	44.7	x	
E 31		61	14	22.9	29	47.5	18	29.5		
E 32	67		11	16.4	28	41.7	28	41.7	x	
E 32		61	16	26.2	25	40.9	20	32.7		
E 33	67		8	11.9	26	38.8	33	49.2		x
E 33		61	19	31.1	19	31.1	23	37.7		

APPENDIX R --Continued

Subject Matter	Category*		Degree of Emphasis						Hypothesis	
	No.		Discussed Briefly**		Discussed in General		Discussed in Detail			
	Sup.	Op.	No.	%	No.	%	No.	%	Retain	Reject
E 34	67		11	16.4	24	35.8	32	47.7	x	
E 34		61	11	18.0	16	26.2	34	55.7		
E 35	67		9	13.4	25	37.3	33	49.2	x	
E 35		61	12	19.6	21	34.4	28	45.9		
E 36	67		8	11.9	26	38.8	33	49.2	x	
E 36		61	14	22.9	26	42.6	21	34.4		
E 37	67		8	11.9	28	41.7	31	46.2	x	
E 37		61	15	24.5	27	44.2	19	31.1		
E 38	67		8	11.9	21	31.3	38	56.7		x
E 38		61	21	34.4	14	22.9	26	42.6		
E 39	67		8	11.9	20	29.8	39	58.2	x	
E 39		61	12	19.6	13	21.3	36	59.0		
E 40	67		8	11.9	16	23.8	43	64.1	x	
E 40		61	10	16.3	12	19.6	39	63.9		
E 41	67		8	11.9	21	31.3	38	56.7	x	
E 41		61	13	21.3	12	19.6	36	59.0		

APPENDIX S

REJECTED ITEMS OF SUBJECT MATTER

		Subject Matter	Mfg.-S.C.	Sup.-Op.
A	1	Operator's ability to use	x	
A	8	Degreasing processes		x
A	16	Application to surfaces		x
A	26	Wet procedure	x	
A	27	Drying time	x	
A	28	Dry procedure	x	
A	30	Procedures		x
A	35	Surface crack recognition		x
A	40	Need for standards		x
B	8	Theory of magnetism		x
B	28	Crack types		x
B	29	Laps, seams, and pits		x
B	36	Procedures		x
B	50	Use of standards		x
C	1	Operator's ability to use	x	x
C	21	Primary coil characteristics	x	
C	23	Coupling factors	x	
C	54	Use of standards		x
D	1	Operator's ability to use	x	
D	4	Amplitude and transit-time	x	
D	13	B-scan system	x	
D	14	C-scan system	x	
D	27	Characteristics and principle		x
D	28	Frequencies and ranges		x
D	34	Attenuation		x
D	36	Refraction	x	
D	37	Diffraction	x	
D	38	Dispersion	x	
D	39	Mode conversion	x	
D	51	Energy-noise discrimination	x	
D	52	Size of defect determination	x	
E	2	Purpose of types	x	
E	11	Electronic sources		x
E	13	Sensitivity	x	

APPENDIX S --Continued

Subject Matter	Mfg.-S. C.	Sup.-Op.
E 26 Focal spot and window	x	
E 27 Electromagnetic waves	x	
E 28 Types of methods		x
E 29 Voltage and amperage	x	
E 31 Exposure factors	x	
E 33 Film characteristics		x
E 37 Penetrameters	x	
E 38 Film processing		x

APPENDIX T

RECOMMENDED TIME TO BE SPENT IN TEACHING

SUBJECT MATTER

Subject	Less Than 1 Hour		From 1 to 2 Hours		From 2 to 3 Hours		More Than 3 Hours	
	No.	%	No.	%	No.	%	No.	%
1 A	37	28.9	43	33.5	35	27.3	13	10.1
2 A	64	50.0	42	32.8	21	16.4	1	.07
3 A	62	48.4	45	35.1	18	14.0	3	2.3
4 A	51	39.8	53	41.4	17	13.2	7	5.4
5 A	49	38.2	45	35.1	28	21.8	6	4.6
6 A	59	46.0	41	32.0	25	19.5	3	2.3
7 A	60	46.8	38	29.6	24	18.7	6	4.6
8 A	72	56.2	31	24.2	24	18.7	1	.07
9 A	73	57.0	36	28.1	16	12.5	3	2.3
10 A	72	56.2	34	26.5	18	14.0	4	3.1
11 A	45	35.1	56	43.7	23	17.9	4	3.1
12 A	57	44.5	43	33.5	24	18.7	4	3.1
13 A	60	46.8	43	33.5	21	16.4	4	3.1
14 A	65	50.7	45	35.1	14	10.9	4	3.1
15 A	61	47.6	46	35.9	20	15.6	1	.07
16 A	57	44.5	49	38.2	21	16.4	1	.07
17 A	78	60.9	36	28.1	14	10.9	-	- -

APPENDIX T --Continued

Subject	Less Than 1 Hour		From 1 to 2 Hours		From 2 to 3 Hours		More Than 3 Hours	
	No.	%	No.	%	No.	%	No.	%
18 A	64	50.0	35	27.3	27	21.0	2	1.5
19 A	63	49.2	41	32.0	23	17.9	-	- -
20 A	64	50.0	39	30.4	20	15.6	5	3.9
21 A	82	64.0	32	25.0	13	10.1	1	.07
22 A	70	54.6	42	32.8	15	11.7	1	.07
23 A	79	61.7	33	25.7	15	11.7	1	.07
24 A	69	53.9	34	26.5	22	17.1	3	2.3
25 A	58	45.3	43	33.5	25	19.5	2	1.5
26 A	61	47.6	48	37.5	18	14.0	1	.07
27 A	70	54.6	34	26.5	23	17.9	1	.07
28 A	67	52.3	36	28.1	24	18.7	1	.07
29 A	61	47.6	40	31.2	22	17.1	5	3.9
30 A	33	25.7	65	50.7	20	15.6	10	7.8
31 A	65	50.7	38	29.6	23	17.9	2	1.5
32 A	73	57.0	42	32.8	11	8.5	2	1.5
33 A	74	57.8	41	32.0	12	9.3	1	.07
34 A	69	53.9	37	28.9	19	14.8	3	2.3
35 A	38	29.6	52	40.6	30	23.4	8	6.2
36 A	46	35.9	48	37.5	29	22.6	5	3.9
37 A	34	26.5	54	42.1	32	25.0	8	6.2
38 A	54	42.1	45	35.1	24	18.7	5	3.9
39 A	64	50.0	40	31.2	20	15.6	4	3.1
40 A	36	28.1	61	47.6	22	17.1	9	7.0
41 A	37	28.9	62	48.4	27	21.0	2	1.5

APPENDIX T --Continued

Subject	Less Than 1 Hour		From 1 to 2 Hours		From 2 to 3 Hours		More Than 3 Hours	
	No.	%	No.	%	No.	%	No.	%
1 B	32	25.0	43	33.5	31	24.2	22	17.1
2 B	55	42.9	42	32.8	27	21.0	4	3.1
3 B	49	38.2	40	31.2	34	26.5	5	3.9
4 B	62	48.4	44	34.3	19	14.8	3	2.3
5 B	54	42.1	53	41.4	15	11.7	6	4.6
6 B	52	40.6	51	39.8	20	15.6	5	3.9
7 B	59	46.0	40	31.2	23	17.9	6	4.6
8 B	29	22.6	52	40.6	31	24.2	16	12.5
9 B	25	19.5	56	43.7	34	26.5	13	10.1
10 B	40	31.2	46	35.9	33	25.7	9	7.0
11 B	41	32.0	50	39.0	28	21.8	9	7.0
12 B	53	41.4	48	37.5	23	17.9	4	3.1
13 B	56	43.7	45	35.1	20	15.6	7	5.4
14 B	62	48.4	34	26.5	26	20.3	6	4.6
15 B	32	25.0	63	49.2	23	17.9	10	7.8
16 B	42	32.8	56	43.7	24	18.7	6	4.6
17 B	45	35.1	54	42.1	22	17.1	7	5.4
18 B	40	31.2	58	45.3	25	19.5	5	3.9
19 B	52	40.6	54	42.1	18	14.0	4	3.1
20 B	51	39.8	52	40.6	21	16.4	4	3.1
21 B	57	44.5	52	40.6	16	12.5	3	2.3
22 B	56	43.7	56	43.7	12	9.3	4	3.1
23 B	70	54.6	43	33.5	12	9.3	3	2.3
24 B	52	40.6	53	41.4	16	12.5	5	3.9

APPENDIX T --Continued

Subject	Less Than 1 Hour		From 1 to 2 Hours		From 2 to 3 Hours		More Than 3 Hours	
	No.	%	No.	%	No.	%	No.	%
25 B	56	43.7	48	37.5	20	15.6	4	3.1
26 B	60	46.8	48	37.5	18	14.0	2	1.5
27 B	57	44.0	51	39.8	17	13.2	3	2.3
28 B	38	29.6	50	39.0	30	23.4	10	7.8
29 B	43	33.5	51	39.8	25	19.5	9	7.0
30 B	51	39.8	50	39.0	17	13.2	10	7.8
31 B	39	30.4	52	40.6	32	25.0	5	3.9
32 B	38	29.6	53	41.4	27	21.0	10	7.8
33 B	45	35.1	54	42.1	23	17.9	6	4.6
34 B	45	35.1	51	39.8	25	19.5	7	5.4
35 B	45	35.1	48	37.5	27	21.0	8	6.2
36 B	37	28.9	54	42.1	27	21.0	10	7.8
37 B	56	43.7	41	32.0	23	17.9	8	6.2
38 B	60	46.8	50	39.0	14	10.9	4	3.1
39 B	70	54.6	38	29.6	16	12.5	4	3.1
40 B	70	54.6	36	28.1	16	12.5	6	4.6
41 B	46	35.9	57	44.5	18	14.0	7	5.4
42 B	64	50.0	36	28.1	20	15.6	8	6.2
43 B	49	38.2	45	35.1	26	20.3	8	6.2
44 B	37	28.9	48	37.5	30	23.4	13	10.1
45 B	69	53.9	27	21.0	27	21.0	5	3.9
46 B	54	42.1	48	37.5	18	14.0	8	6.2
47 B	46	35.9	54	42.1	20	15.6	8	6.2
48 B	53	41.4	47	36.7	20	15.6	8	6.2

APPENDIX T --Continued

Subject	Less Than 1 Hour		From 1 to 2 Hours		From 2 to 3 Hours		More Than 3 Hours	
	No.	%	No.	%	No.	%	No.	%
49 B	44	34.3	54	42.1	25	19.5	5	3.9
50 B	47	36.7	40	31.2	25	19.5	16	12.5
51 B	28	21.8	43	33.5	37	28.9	20	15.6
1 C	40	31.2	40	31.2	26	20.3	22	17.1
2 C	37	28.9	59	46.0	23	17.9	9	7.0
3 C	58	45.3	45	35.1	20	15.6	5	3.9
4 C	50	39.0	55	42.9	17	13.2	6	4.6
5 C	49	38.2	39	30.4	35	27.3	5	3.9
6 C	51	39.8	62	48.4	13	10.1	2	1.5
7 C	54	42.1	48	37.5	23	17.9	3	2.3
8 C	55	42.9	57	44.5	14	10.1	2	1.5
9 C	61	47.6	45	35.1	20	15.6	2	1.5
10 C	57	44.5	61	47.6	9	7.0	1	.07
11 C	54	42.1	55	42.9	19	14.8	-	- -
12 C	64	50.0	43	33.5	19	14.8	2	1.5
13 C	63	49.2	42	32.8	22	17.1	-	- -
14 C	56	43.7	53	41.4	17	13.2	2	1.5
15 C	56	43.7	50	39.0	19	14.8	3	2.3
16 C	51	39.8	53	41.4	19	14.8	5	3.9
17 C	35	27.5	44	34.3	28	21.8	21	16.4
18 C	40	31.2	55	42.9	26	20.3	7	5.4
19 C	51	39.8	50	39.0	24	18.7	3	2.3
20 C	48	37.5	44	34.3	33	25.7	3	2.3
21 C	51	39.8	48	37.5	27	21.0	2	1.5

APPENDIX T --Continued

Subject	Less Than 1 Hour		From 1 to 2 Hours		From 2 to 3 Hours		More Than 3 Hours	
	No.	%	No.	%	No.	%	No.	%
22 C	48	37.5	52	40.6	26	20.3	2	1.5
23 C	48	37.5	48	37.5	27	21.0	5	3.9
24 C	59	46.0	49	38.2	16	12.5	4	3.1
25 C	57	44.5	44	34.3	18	14.0	9	7.0
26 C	61	47.6	44	34.3	16	12.5	7	5.4
27 C	58	45.3	42	32.8	24	18.7	4	3.1
28 C	60	46.8	48	37.5	17	13.2	3	2.3
29 C	54	42.1	49	38.2	21	16.4	4	3.1
30 C	58	45.3	47	36.7	19	14.8	4	3.1
31 C	63	49.2	52	40.6	10	7.8	3	2.3
32 C	52	40.6	48	37.5	22	17.1	6	4.6
33 C	59	46.0	48	37.5	16	12.5	5	3.9
34 C	60	46.8	39	30.4	22	17.1	7	5.4
35 C	54	42.1	50	39.0	19	14.8	5	3.9
36 C	51	39.8	61	47.6	12	9.3	4	3.1
37 C	38	29.6	42	32.8	38	29.6	10	7.8
38 C	53	41.4	48	37.5	24	18.7	3	2.3
39 C	49	38.2	52	40.6	27	21.0	-	- -
40 C	53	41.4	51	39.8	21	16.4	3	2.3
41 C	53	41.4	43	33.5	27	21.0	5	3.9
42 C	51	39.8	46	35.9	28	21.8	3	2.3
43 C	54	42.1	38	29.6	32	25.0	4	3.1
44 C	45	35.1	54	42.1	23	17.9	6	4.6
45 C	54	42.1	51	39.8	17	13.2	6	4.6

APPENDIX T --Continued

Subject	Less Than 1 Hour		From 1 to 2 Hours		From 2 to 3 Hours		More Than 3 Hours	
	No.	%	No.	%	No.	%	No.	%
46 C	56	43.7	45	35.1	22	17.1	5	3.9
47 C	49	38.2	47	36.7	21	16.4	11	8.5
48 C	51	39.8	46	35.9	27	21.0	4	3.1
49 C	51	39.8	44	34.3	28	21.8	5	3.9
50 C	52	40.6	42	32.8	30	23.4	4	3.1
51 C	59	46.0	43	33.5	20	15.6	6	4.6
52 C	28	21.8	50	39.0	31	24.2	19	14.8
53 C	41	32.0	36	28.1	39	30.4	12	9.3
54 C	32	25.0	43	33.5	38	29.6	15	11.7
55 C	44	34.3	44	34.3	26	20.3	14	10.9
1 D	31	24.2	35	27.3	25	19.5	37	28.9
2 D	32	25.0	53	41.4	38	29.6	5	3.9
3 D	47	36.7	43	33.5	32	25.0	6	4.6
4 D	48	37.5	42	32.8	31	24.2	7	5.4
5 D	50	39.0	41	32.0	28	21.8	9	7.0
6 D	48	37.5	43	33.5	28	21.8	9	7.0
7 D	50	39.0	44	34.3	28	21.8	6	4.6
8 D	51	39.8	46	35.9	26	20.3	5	3.9
9 D	51	39.8	46	35.9	27	21.0	4	3.1
10 D	50	39.0	54	42.1	19	14.8	5	3.9
11 D	48	37.5	49	38.2	28	21.8	3	2.3
12 D	44	34.3	48	37.5	30	23.4	6	4.6
13 D	46	35.9	43	33.5	31	24.2	8	6.2

APPENDIX T --Continued

Subject	Less Than 1 Hour		From 1 to 2 Hours		From 2 to 3 Hours		More Than 3 Hours	
	No.	%	No.	%	No.	%	No.	%
14 D	43	33.5	47	36.7	29	22.6	9	7.0
15 D	52	40.6	46	35.9	27	21.0	3	2.3
16 D	56	43.7	43	33.5	24	18.7	5	3.9
17 D	42	32.8	45	35.1	35	27.3	6	4.6
18 D	40	31.2	42	32.8	40	31.2	6	4.6
19 D	42	32.8	47	36.7	33	25.7	6	4.6
20 D	49	38.2	47	36.7	26	20.3	6	4.6
21 D	42	32.8	42	32.8	36	28.1	8	6.2
22 D	41	32.0	38	29.6	38	29.6	11	8.5
23 D	54	42.1	44	34.3	24	18.7	6	4.6
24 D	43	33.5	48	37.5	28	21.8	9	7.0
25 D	54	42.1	41	32.0	28	21.8	5	3.9
26 D	55	42.9	37	28.9	29	22.6	7	5.4
27 D	31	24.2	52	40.6	29	22.6	16	12.5
28 D	36	28.1	49	38.2	32	25.0	11	8.5
29 D	52	40.6	47	36.7	24	18.7	5	3.9
30 D	53	41.4	45	35.1	24	18.7	6	4.6
31 D	53	41.4	54	42.1	17	13.2	4	3.1
32 D	50	39.0	45	35.1	31	24.2	2	1.5
33 D	46	35.9	60	46.8	19	14.8	3	2.3
34 D	46	35.9	56	43.7	20	15.6	6	4.6
35 D	45	35.1	59	46.0	20	15.6	4	3.1
36 D	42	32.8	60	46.8	21	16.4	5	3.9
37 D	51	39.8	41	32.0	31	24.2	5	3.9

APPENDIX T --Continued

Subject	Less Than 1 Hour		From 1 to 2 Hours		From 2 to 3 Hours		More Than 3 Hours	
	No.	%	No.	%	No.	%	No.	%
38 D	51	39.8	43	33.5	31	24.2	3	2.3
39 D	46	35.9	44	34.3	29	22.6	9	7.0
40 D	50	39.0	54	42.1	18	14.0	6	4.6
41 D	48	37.5	47	36.7	27	21.0	6	4.6
42 D	34	26.5	46	35.9	33	25.7	15	11.7
43 D	37	28.9	41	32.0	36	28.1	14	10.9
44 D	44	34.3	42	32.8	35	27.3	7	5.4
45 D	48	37.5	36	28.1	36	28.1	8	6.2
46 D	37	28.9	54	42.1	23	17.9	14	10.9
47 D	37	28.9	43	33.5	31	24.2	17	13.2
48 D	33	25.7	51	39.8	33	25.7	11	8.5
49 D	29	22.5	49	38.2	39	30.4	11	8.5
50 D	30	23.4	54	42.1	36	28.1	8	6.2
51 D	41	32.0	53	41.4	24	18.7	10	7.8
52 D	23	17.9	59	46.0	28	21.8	18	14.0
53 D	27	21.0	50	39.0	33	25.7	18	14.0
54 D	24	18.7	41	32.0	42	32.8	21	16.4
55 D	22	17.1	45	35.1	42	32.8	19	14.8
56 D	22	17.1	40	31.2	48	37.5	18	14.0
1 E	31	24.2	34	26.5	27	21.0	36	28.1
2 E	28	21.8	53	41.4	39	30.4	8	6.2
3 E	40	31.2	53	41.4	28	21.8	7	5.4
4 E	40	31.2	44	34.3	34	26.5	10	7.8

APPENDIX T --Continued

Subject	Less Than 1 Hour		From 1 to 2 Hours		From 2 to 3 Hours		More Than 3 Hours	
	No.	%	No.	%	No.	%	No.	%
5 E	28	21.8	60	46.8	32	25.0	8	6.2
6 E	36	28.1	47	36.7	35	27.3	10	7.8
7 E	39	30.4	56	43.7	27	21.0	6	4.6
8 E	16	12.5	41	32.0	46	35.9	25	19.5
9 E	20	15.6	39	30.4	50	39.0	19	14.8
10 E	28	21.8	48	37.5	42	32.8	10	7.8
11 E	36	28.1	47	36.7	36	28.1	9	7.0
12 E	32	25.0	48	37.5	37	28.9	11	8.5
13 E	31	24.2	54	42.1	34	26.5	9	7.0
14 E	40	31.2	45	35.1	37	28.9	6	4.6
15 E	33	25.7	45	35.1	43	33.5	7	5.4
16 E	18	14.0	53	41.4	48	37.5	9	7.0
17 E	40	31.2	45	35.1	35	27.3	8	6.2
18 E	37	28.9	52	40.6	31	24.2	8	6.2
19 E	24	18.7	53	41.4	40	31.2	11	8.5
20 E	32	25.0	57	44.5	30	23.4	9	7.0
21 E	36	28.1	58	45.3	29	22.6	5	3.9
22 E	43	33.5	48	37.5	31	24.2	6	4.6
23 E	17	13.2	47	36.7	48	37.5	16	12.5
24 E	28	21.8	47	36.7	37	28.9	16	12.5
25 E	28	21.8	56	43.7	33	25.7	11	8.5
26 E	37	28.9	54	42.1	32	25.0	5	3.9
27 E	42	32.8	55	42.9	26	20.3	5	3.9
28 E	26	20.3	55	42.9	32	25.0	15	11.7

APPENDIX T --Continued

Subject	Less Than 1 Hour		From 1 to 2 Hours		From 2 to 3 Hours		More Than 3 Hours	
	No.	%	No.	%	No.	%	No.	%
29 E	41	32.0	50	39.0	31	24.2	6	4.6
30 E	51	39.8	44	34.3	26	20.3	7	5.4
31 E	31	24.2	48	37.5	39	30.4	10	7.8
32 E	40	31.2	44	34.3	35	27.3	9	7.0
33 E	32	25.0	46	35.9	40	31.2	10	7.8
34 E	27	21.0	46	35.9	33	25.7	22	17.1
35 E	35	27.3	43	33.5	38	29.6	12	9.3
36 E	40	31.2	35	27.3	41	32.0	12	9.3
37 E	33	25.7	47	36.7	37	28.9	11	8.5
38 E	16	12.5	57	44.5	29	22.6	26	20.3
39 E	18	14.0	47	36.7	35	27.3	28	21.8
40 E	16	12.5	32	25.0	43	33.5	37	28.9
41 E	23	17.9	36	28.1	38	29.6	31	24.2

APPENDIX U

ADDITIONAL SUBJECT MATTER RECOMMENDED IN THE TRAINING OF NDT TECHNICIANS

Automation possibilities
Blueprint reading
Combined systems
Computer support
Equipment maintenance
Hardness testing
Microstructure correlations
Responsibility in detection
Safety factors
Sensitive detection methods
Sensitive instrumentation
Set-up procedures
Signal synthesis
Standards and specifications
Support from professional organizations
Swinging field
Updating equipment
Vibration analysis

APPENDIX V

RECOMMENDED RESEARCH IN NONDESTRUCTIVE TESTING

Accelerated detection methods
Dyes
Economics
Energy travel
Evaluation and acceptance
Film contrast
Grain size influences
Graphite nozzle endurance
Hardness correlations
Large vessel scanning
Liner life factors
Mobility capability
Mode conversions
Non-metallic values
Nuclear reactor associations
Optical recognition systems
Probe developments in restricted areas
Reliability
Remote operations
Rocket motor endurance
Shape geometry and defect recognition
Specific gravity associations
Transducers

APPENDIX W

OTHER FORMS OF ENERGY WHICH MAY BE UTILIZED IN SUPPORT OF NONDESTRUCTIVE TESTING

Acoustic emission
Chamberscope
Coherent light
Color
Electron
Fluoroscopic
Gamma ray
Heat
Holographic
Hydrostatic
Infrared
Laser
Liquid crystal
Low frequency sound
Magnetic rubber
Nuclear
Oblique lighting
Optical
Sonic
Thermal
Three dimensional
Varying wave
Vibration
Visible light

APPENDIX X

OTHER BRANCHES OF INDUSTRY THAT SHOULD BE SUPPORTED WITH NONDESTRUCTIVE TESTING PROCESSES

Appliance inspections
Architecture and bridges
Casting
Corrosion control
Farm equipment
Forging and rolling
General engineering
General manufacture
Heat treating processes
Heavy manufacturing
Legal areas requiring standards
Loaded structures
Maintenance
Marine parts
Medical
Nuclear
Oil and gas industry
Pipelines
Pressure vessels
Railroad industry
Reliability testing
Steel mills

APPENDIX Y

ADDITIONAL PROGRAM DEVELOPMENT
RECOMMENDATIONS

Codes and specifications training
Equipment familiarization
Factory training
Field trips
Good laboratory facilities
Legislative proposals
Other areas of NDT familiarization
Publicized shortage in NDT
Safety practice indoctrination
Vibration analysis

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